## codeGen.cpp

#include "codeGen.hpp"  
   
 CodeGenarator::CodeGenarator(string outputFile, ASTNode \*root, SymbolTable \*symbolTable)  
 : \_outputFile(outputFile), \_root(root), \_functions(symbolTable->getFunctions()), \_currFunctionIndex(0) {}  
   
 void CodeGenarator::genCode()  
 {  
 floatMacroCodeGen();  
   
 \_outputFile << ".data\n";  
 \_outputFile << "format\_int db \"%d \", 10, 0\n";  
 \_outputFile << "format\_float db \"%lf \", 10, 0\n";  
 \_outputFile << "\n.code\n";  
 \_outputFile << "extern ExitProcess : proc\n";  
   
 \_outputFile << "extern printf : proc\n";  
   
 \_outputFile << "\nmain PROC\n";  
 \_outputFile << "\tcall function\_main\n";  
 \_outputFile << "\tmov ecx, eax\n";  
 \_outputFile << "\tcall ExitProcess\n";  
 \_outputFile << " main ENDP\n";  
 printIntFuncCodeGen();  
 printFloatFuncCodeGen();  
 vector<NonTerminalNode \*> funcDeclNodes = getFunctionDeclNodes((NonTerminalNode \*)\_root);  
 int j = 0;  
 for (int i = NUM\_OF\_BUILT\_IN\_FUNCTIONS; i < \_functions.size(); i++)  
 {  
 \_currFunctionIndex = i;  
   
 funcCodeGen(funcDeclNodes[j++]);  
 }  
   
 \_outputFile << "\n\nEND";  
 \_outputFile.close();  
 }  
   
 void CodeGenarator::funcCodeGen(NonTerminalNode \*node)  
 {  
 \_scopeStack.push(getCurrFunctionEntry()->getInnerScope());  
 string funcName = getCurrFunctionEntry()->getName();  
 \_outputFile << "\n"  
 << \_lableManager.getFunctionLable(funcName) << ":\n";  
 \_outputFile << "\tpush rbp\n";  
 \_outputFile << "\tmov rbp, rsp\n";  
   
 int offset = assignStackOffset(getCurrFunctionEntry()->getInnerScope());  
   
 \_outputFile << "\tsub rsp, " << offset << "\n";  
 loadFunctionVariables(getCurrFunctionEntry());  
   
 stmtListCodeGen((NonTerminalNode \*)node->GetChildren()[8]);  
   
 \_outputFile << \_lableManager.getFunctionEpilogueLable(funcName) << ":\n";  
 \_outputFile << "\tmov rsp, rbp\n";  
 \_outputFile << "\tpop rbp\n";  
 \_outputFile << "\tret\n";  
 \_scopeStack.pop();  
 }  
   
 void CodeGenarator::stmtListCodeGen(NonTerminalNode \*node)  
 {  
 vector<NonTerminalNode \*> children = getStmtNodes(node);  
 for (NonTerminalNode \*child : children)  
 {  
 stmtCodeGen((NonTerminalNode \*)child);  
 }  
 }  
   
 void CodeGenarator::stmtCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*firstChild = (NonTerminalNode \*)children[0];  
 if (firstChild->getNonTerminalKind() == SIMPLE\_STMT)  
 {  
 simpleStmtCodeGen(firstChild);  
 }  
   
 else if (firstChild->getNonTerminalKind() == IF\_STMT)  
 {  
 ifStmtCodeGen(firstChild);  
 }  
   
 else if (firstChild->getNonTerminalKind() == WHILE\_STMT)  
 {  
 whileStmtCodeGen(firstChild);  
 }  
   
 else if (firstChild->getNonTerminalKind() == FOR\_STMT)  
 {  
 forStmtCodeGen(firstChild);  
 }  
 }  
   
 void CodeGenarator::simpleStmtCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*firstChild = (NonTerminalNode \*)children[0];  
   
 if (isReturnStatement(node))  
 {  
 ASTNode \*exprOptNode = node->GetChildren()[1];  
 if (!exprOptNode->GetChildren().empty())  
 {  
 exprOptCodeGen((NonTerminalNode \*)exprOptNode);  
 \_outputFile << "\tmov rax, " << \_scratchManager.getName(exprOptNode->GetRegister()) << "\n";  
 \_scratchManager.free(exprOptNode->GetRegister());  
 }  
 \_outputFile << "\tjmp " << \_lableManager.getFunctionEpilogueLable(getCurrFunctionEntry()->getName()) << "\n";  
 \_outputFile << endl;  
 }  
   
 if (firstChild->getNonTerminalKind() == VAR\_DECL\_EXPR)  
 {  
 varDeclExprCodeGen(firstChild);  
 }  
   
 if (isFuncCall(node))  
 {  
 callExprCodeGen(node);  
 \_scratchManager.free(node->GetRegister());  
 }  
   
 if (firstChild->getNonTerminalKind() == ASSIGN\_EXPR)  
 {  
 assignExpressionCodeGen((NonTerminalNode \*)firstChild);  
   
 int reg = firstChild->GetRegister();  
 \_scratchManager.free(reg);  
 }  
 }  
   
 void CodeGenarator::varDeclExprCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> varDeclChildren = node->GetChildren();  
 NonTerminalNode \*initOptNode = (NonTerminalNode \*)varDeclChildren[2];  
   
 if (initOptNode->GetChildren().size() != 0)  
 {  
 NonTerminalNode \*assignValueNode = (NonTerminalNode \*)(initOptNode->GetChildren()[1]);  
 NonTerminalNode \*exprNode = (NonTerminalNode \*)(assignValueNode->GetChildren()[0]);  
   
 exprCodeGen(exprNode);  
 int reg = exprNode->GetRegister();  
 storeMem(getVarAddr(((TerminalNode \*)varDeclChildren[1])->getToken()->val), reg);  
 \_scratchManager.free(reg);  
 }  
 }  
   
 void CodeGenarator::ifStmtCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*conditionOpNode = (NonTerminalNode \*)children[2];  
   
 int elseLabel = \_lableManager.create();  
 int endLabel = \_lableManager.create();  
   
 conditionOptionCodeGen(conditionOpNode);  
 compareToZero(conditionOpNode->GetRegister());  
 \_outputFile << "\tjz " << \_lableManager.getName(elseLabel) << "\n";  
 bodyCodeGen((NonTerminalNode \*)children[4]);  
 \_outputFile << "\tjmp " << \_lableManager.getName(endLabel) << "\n";  
 \_outputFile << \_lableManager.getName(elseLabel) << ":\n";  
   
 if (children.size() == 7)  
 {  
 bodyCodeGen((NonTerminalNode \*)children[6]);  
 }  
   
 \_outputFile << \_lableManager.getName(endLabel) << ":\n";  
 }  
   
 void CodeGenarator::conditionOptionCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*firstChild = (NonTerminalNode \*)children[0];  
   
 if (firstChild->getNonTerminalKind() == EXPR)  
 {  
 exprCodeGen(firstChild);  
 }  
 else if (firstChild->getNonTerminalKind() == ASSIGN\_EXPR)  
 {  
 assignExpressionCodeGen(firstChild);  
 }  
   
 node->SetRegister(firstChild->GetRegister());  
 }  
   
 void CodeGenarator::whileStmtCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*conditionOpNode = (NonTerminalNode \*)children[2];  
   
 int startLabel = \_lableManager.create();  
 int endLabel = \_lableManager.create();  
   
 \_outputFile << \_lableManager.getName(startLabel) << ":\n";  
   
 conditionOptionCodeGen(conditionOpNode);  
   
 compareToZero(conditionOpNode->GetRegister());  
 \_outputFile << "\tjz " << \_lableManager.getName(endLabel) << "\n";  
 bodyCodeGen((NonTerminalNode \*)children[4]);  
 \_outputFile << "\tjmp " << \_lableManager.getName(startLabel) << "\n";  
 \_outputFile << \_lableManager.getName(endLabel) << ":\n";  
 }  
   
 void CodeGenarator::forStmtCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*forIntNode = (NonTerminalNode \*)children[2];  
 NonTerminalNode \*exprOpNode = (NonTerminalNode \*)children[4];  
 NonTerminalNode \*incrementOptNode = (NonTerminalNode \*)children[6];  
   
 int startLabel = \_lableManager.create();  
 int endLabel = \_lableManager.create();  
   
 forInitCodeGen(forIntNode);  
   
 \_outputFile << \_lableManager.getName(startLabel) << ":\n";  
   
 exprOptCodeGen(exprOpNode);  
 compareToZero(exprOpNode->GetRegister());  
 \_outputFile << "\tjz " << \_lableManager.getName(endLabel) << "\n";  
 bodyCodeGen((NonTerminalNode \*)children[8]);  
   
 forUpdateCodeGen(incrementOptNode);  
   
 \_outputFile << "\tjmp " << \_lableManager.getName(startLabel) << "\n";  
 \_outputFile << \_lableManager.getName(endLabel) << ":\n";  
 }  
   
 void CodeGenarator::forInitCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 if (children.size() != 0)  
 {  
 NonTerminalNode \*firstChild = (NonTerminalNode \*)children[0];  
 if (firstChild->getNonTerminalKind() == VAR\_DECL\_EXPR)  
 {  
 exprCodeGen(firstChild);  
 \_scratchManager.free(firstChild->GetRegister());  
 }  
 else if (firstChild->getNonTerminalKind() == ASSIGN\_EXPR)  
 {  
 assignExpressionCodeGen(firstChild);  
 }  
 }  
 }  
   
 void CodeGenarator::forUpdateCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 if (children.size() != 0)  
 {  
 NonTerminalNode \*firstChild = (NonTerminalNode \*)children[0];  
 if (firstChild->getNonTerminalKind() == ASSIGN\_EXPR)  
 {  
 assignExpressionCodeGen(firstChild);  
 }  
   
 else if (firstChild->getNonTerminalKind() == INCREMENT\_EXPR)  
 {  
 incrementExprCodeGen(firstChild);  
 }  
 }  
 }  
   
 void CodeGenarator::bodyCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*firstChild = (NonTerminalNode \*)children[0];  
   
 if (children.size() == 3)  
 {  
 stmtListCodeGen((NonTerminalNode \*)children[1]);  
 }  
 else if (children.size() == 2)  
 {  
 simpleStmtCodeGen((NonTerminalNode \*)children[0]);  
 }  
 else if (firstChild->getNonTerminalKind() == IF\_STMT)  
 {  
 ifStmtCodeGen((NonTerminalNode \*)firstChild);  
 }  
 else if (firstChild->getNonTerminalKind() == WHILE\_STMT)  
 {  
 whileStmtCodeGen((NonTerminalNode \*)firstChild);  
 }  
 else if (firstChild->getNonTerminalKind() == FOR\_STMT)  
 {  
 forStmtCodeGen((NonTerminalNode \*)firstChild);  
 }  
 }  
 void CodeGenarator::assignExpressionCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 NonTerminalNode \*leftExprNode = (NonTerminalNode \*)children[0];  
 NonTerminalNode \*rightExprNode = (NonTerminalNode \*)children[2];  
   
 exprCodeGen(rightExprNode);  
 int reg = rightExprNode->GetRegister();  
   
 if(leftExprNode->GetChildren().size() == 2)  
 {  
 storeMemPtrValue(getVarAddr(((TerminalNode \*)leftExprNode->GetChildren()[1])->getToken()->val), reg);  
 }else  
 {  
 storeMem(getVarAddr(((TerminalNode \*)leftExprNode->GetChildren()[0])->getToken()->val), reg);  
 }  
   
 node->SetRegister(reg);  
 }  
   
 void CodeGenarator::exprOptCodeGen(NonTerminalNode \*node)  
 {  
 if (!node->GetChildren().empty())  
 {  
 exprCodeGen(node->GetChildren()[0]);  
 node->SetRegister(node->GetChildren()[0]->GetRegister());  
 }  
 }  
   
 void CodeGenarator::exprCodeGen(ASTNode \*node)  
 {  
 ASTNode \*child = node->GetChildren()[0];  
 if (child->GetType() == NON\_TERMINAL) {  
 auto nt = (NonTerminalNode\*)child;  
 switch (nt->getNonTerminalKind()) {  
 case LOGICAL\_EXPR:  
 logicalExprCodeGen(nt);  
 break;  
 case ADDRESS\_EXPR:  
 addressExprCodeGen(nt);  
 break;  
 case PRIMARY\_EXPR:  
 primaryExprCodeGen(nt);  
 break;  
 }  
 }  
 node->SetRegister(child->GetRegister());  
 }  
   
   
 void CodeGenarator::logicalExprCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
   
 if (children.size() == 1)  
 {  
 relationalExprCodeGen((NonTerminalNode \*)children[0]);  
 node->SetRegister(children[0]->GetRegister());  
 return;  
 }  
   
 logicalExprCodeGen((NonTerminalNode \*)children[0]);  
 relationalExprCodeGen((NonTerminalNode \*)children[2]);  
   
 int leftReg = children[0]->GetRegister();  
 int rightReg = children[2]->GetRegister();  
   
 string left = \_scratchManager.getName(leftReg);  
 string right = \_scratchManager.getName(rightReg);  
   
 SyntaxKind opKind = ((TerminalNode \*)children[1])->getTerminalKind();  
   
 string resultReg = left;  
   
 // Compare both sides to zero  
 \_outputFile << "\tcmp " << left << ", 0\n";  
 \_outputFile << "\tsetne al\n";  
 \_outputFile << "\tmovzx " << left << ", al\n";  
   
 \_outputFile << "\tcmp " << right << ", 0\n";  
 \_outputFile << "\tsetne al\n";  
 \_outputFile << "\tmovzx " << right << ", al\n";  
   
 if (opKind == PIPE\_PIPE)  
 {  
 \_outputFile << "\tor " << left << ", " << right << "\n";  
 }  
 else if (opKind == AMPERSAND\_AMPERSAND)  
 {  
 \_outputFile << "\tand " << left << ", " << right << "\n";  
 }  
   
 node->SetRegister(leftReg);  
 \_scratchManager.free(rightReg);  
 }  
   
 void CodeGenarator::relationalExprCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 if (children.size() == 1)  
 {  
 addExprCodeGen((NonTerminalNode \*)children[0]);  
 node->SetRegister(children[0]->GetRegister());  
 return;  
 }  
   
 relationalExprCodeGen((NonTerminalNode \*)children[0]);  
 addExprCodeGen((NonTerminalNode \*)children[2]);  
   
 int leftReg = children[0]->GetRegister();  
 int rightReg = children[2]->GetRegister();  
   
 \_outputFile << "\tcmp " << \_scratchManager.getName(leftReg) << ", " << \_scratchManager.getName(rightReg) << "\n";  
   
 SyntaxKind opKind = ((TerminalNode \*)children[1])->getTerminalKind();  
 string instr;  
 if (opKind == LESS\_THAN)  
 instr = "setl";  
 else if (opKind == LESS\_THAN\_EQUALS)  
 instr = "setle ";  
 else if (opKind == GREATER\_THAN)  
 instr = "setg";  
 else if (opKind == GREATER\_THAN\_EQUALS)  
 instr = "setge";  
 else if (opKind == EQUALS\_EQUALS)  
 instr = "sete";  
 else if (opKind == BANG\_EQUALS)  
 instr = "setne";  
   
 \_outputFile << "\t" << instr << " al\n";  
 \_outputFile << "\tmovzx " << \_scratchManager.getName(leftReg) << ", al\n";  
   
 node->SetRegister(leftReg);  
 \_scratchManager.free(rightReg);  
 }  
   
 void CodeGenarator::addExprCodeGen(NonTerminalNode \*node)  
 {  
 auto &children = node->GetChildren();  
 if (children.size() == 1)  
 {  
 mulExprCodeGen((NonTerminalNode \*)children[0]);  
 node->SetRegister(children[0]->GetRegister());  
 return;  
 }  
   
 addExprCodeGen((NonTerminalNode \*)children[0]);  
 mulExprCodeGen((NonTerminalNode \*)children[2]);  
   
 int leftReg = children[0]->GetRegister();  
 int rightReg = children[2]->GetRegister();  
   
 SyntaxKind opKind = ((TerminalNode \*)children[1])->getTerminalKind();  
 string op;  
 if (opKind == PLUS)  
 op = "add";  
 else if (opKind == MINUS)  
 op = "sub";  
 else if (opKind == PIPE)  
 op = "or";  
 else if (opKind == CARET)  
 op = "xor";  
   
 \_outputFile << "\t" << op << " " << \_scratchManager.getName(leftReg) << ", " << \_scratchManager.getName(rightReg) << "\n";  
   
 node->SetRegister(leftReg);  
 \_scratchManager.free(rightReg);  
 }  
   
 void CodeGenarator::mulExprCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 if (children.size() == 1)  
 {  
 unaryExprCodeGen((NonTerminalNode \*)children[0]);  
 node->SetRegister(children[0]->GetRegister());  
 return;  
 }  
   
 mulExprCodeGen((NonTerminalNode \*)children[0]);  
 unaryExprCodeGen((NonTerminalNode \*)children[2]);  
   
 int leftReg = children[0]->GetRegister();  
 int rightReg = children[2]->GetRegister();  
   
 SyntaxKind opKind = ((TerminalNode \*)children[1])->getTerminalKind();  
 if (opKind == STAR)  
 {  
 \_outputFile << "\timul " << \_scratchManager.getName(leftReg) << ", " << \_scratchManager.getName(rightReg) << "\n";  
 }  
 else if (opKind == SLASH)  
 {  
 \_outputFile << "\tmov rax, " << \_scratchManager.getName(leftReg) << "\n";  
 \_outputFile << "\tcqo\n";  
 \_outputFile << "\tidiv " << \_scratchManager.getName(rightReg) << "\n";  
 \_outputFile << "\tmov " << \_scratchManager.getName(leftReg) << ", rax\n";  
 }  
 else if (opKind == AMPERSAND)  
 {  
 \_outputFile << "\tand " << \_scratchManager.getName(leftReg) << ", " << \_scratchManager.getName(rightReg) << "\n";  
 }  
   
 node->SetRegister(leftReg);  
 \_scratchManager.free(rightReg);  
 }  
   
 void CodeGenarator::unaryExprCodeGen(NonTerminalNode \*node)  
 {  
 vector<ASTNode \*> children = node->GetChildren();  
 if (children.size() == 1)  
 {  
 primaryExprCodeGen((NonTerminalNode \*)children[0]);  
 node->SetRegister(children[0]->GetRegister());  
 return;  
 }  
   
 unaryExprCodeGen((NonTerminalNode \*)children[1]);  
 int reg = children[1]->GetRegister();  
 node->SetRegister(reg);  
   
 SyntaxKind op = ((TerminalNode \*)children[0])->getTerminalKind();  
 if (op == MINUS)  
 neg(reg);  
 else if (op == BANG)  
 {  
 compareToZero(reg);  
 \_outputFile << "\tsete al\n";  
 \_outputFile << "\tmovzx " << \_scratchManager.getName(reg) << ", al\n";  
 }  
 }  
   
   
 void CodeGenarator::primaryExprCodeGen(NonTerminalNode \*node)  
 {  
 std::vector<ASTNode\*> children = node->GetChildren();  
 ASTNode \*first = children[0];  
   
 // 1) if it's a nested non-terminal for \* or ++/--, delegate immediately  
 if (first->GetType() == NON\_TERMINAL) {  
 NonTerminalNode \*nt = (NonTerminalNode\*) first;  
 if (nt->getNonTerminalKind() == DEREFERENCE\_EXPR) {  
 dereferenceExprCodeGen(nt);  
 node->SetRegister(nt->GetRegister());  
 return;  
 }  
 if (nt->getNonTerminalKind() == INCREMENT\_EXPR) {  
 incrementExprCodeGen(nt);  
 node->SetRegister(nt->GetRegister());  
 return;  
 }  
 }  
   
 TerminalNode \*tNode = (TerminalNode\*) first;  
 SyntaxToken \*tok = tNode->getToken();  
   
 // integer literal  
 if (tok->kind == INTEGER\_LITERAL) {  
 int r = \_scratchManager.alloc();  
 \_outputFile << "\tmov " << \_scratchManager.getName(r)  
 << ", " << tok->val << "\n";  
 node->SetRegister(r);  
 }  
 // float literal  
 else if (tok->kind == FLOAT\_LITERAL) {  
 int r = \_scratchManager.allocFloat();  
 \_outputFile << "\tmovsd " << \_scratchManager.getName(r)  
 << ", FP8(" << tok->val << ")\n";  
 node->SetRegister(r);  
 }  
 // simple variable load  
 else if (tok->kind == IDENTIFIER && children.size() == 1) {  
 int r = \_scratchManager.alloc();  
 loadMem(getVarAddr(tok->val), r);  
 node->SetRegister(r);  
 }  
 // parenthesized expression: ( Expr )  
 else if (tok->kind == OPEN\_PAREN && children.size() == 3) {  
 exprCodeGen(children[1]);  
 node->SetRegister(children[1]->GetRegister());  
 }  
 // function call: IDENTIFIER OPEN\_PAREN ExprList CLOSED\_PAREN  
 else if (isFuncCall(node)) {  
 callExprCodeGen(node);  
 }  
   
 }  
   
   
 void CodeGenarator::callExprCodeGen(NonTerminalNode \*node)  
 {  
 string funcName = ((TerminalNode \*)node->GetChildren()[0])->getToken()->val;  
 vector<NonTerminalNode \*> args = getFunctionCallArgsNodes((NonTerminalNode \*)node->GetChildren()[2]);  
   
 pushArgs(args);  
   
 \_outputFile << "\tcall " << \_lableManager.getFunctionLable(funcName) << "\n";  
   
 valType funcRetType = getCurrFunctionEntry()->getReturnType();  
 int reg;  
   
 if (funcRetType.type == FLOAT)  
 {  
 reg = \_scratchManager.allocFloat();  
 \_outputFile << "\tmovsd " << \_scratchManager.getName(reg) << ", xmm0\n";  
 }  
 else  
 {  
 reg = \_scratchManager.alloc();  
 \_outputFile << "\tmov " << \_scratchManager.getName(reg) << ", rax\n";  
 node->SetRegister(reg);  
 }  
   
 node->SetRegister(reg);  
 }  
   
 void CodeGenarator::pushArgs(vector<NonTerminalNode \*> args)  
 {  
 for (int i = args.size() - 1; i >= 0; i--)  
 {  
 NonTerminalNode \*arg = args[i];  
 exprCodeGen(arg);  
 push(arg->GetRegister());  
 \_scratchManager.free(arg->GetRegister());  
 }  
 }  
 void CodeGenarator::incrementExprCodeGen(NonTerminalNode \*node)  
 {  
 auto kids = node->GetChildren();  
 TerminalNode \*opNode = ((TerminalNode \*)kids[0])->getTerminalKind() != IDENTIFIER ? (TerminalNode \*)kids[0] : (TerminalNode \*)kids[1];  
 TerminalNode \*idNode = ((TerminalNode \*)kids[0])->getTerminalKind() == IDENTIFIER ? (TerminalNode \*)kids[0] : (TerminalNode \*)kids[1];  
 SyntaxKind op = opNode->getTerminalKind();  
   
 string opCommand = (op == PLUS\_PLUS) ? "inc" : "dec";  
 bool isPost = ((TerminalNode \*)kids[0])->getTerminalKind() == IDENTIFIER;  
   
 tableEntry varEntry = \_scopeStack.top()->getEntry(idNode->getToken()->val);  
 int reg = \_scratchManager.alloc();  
 int tempReg = \_scratchManager.alloc();  
 loadMem(varEntry.addr, tempReg);  
   
 if (isPost)  
 {  
 mov(\_scratchManager.getName(reg), \_scratchManager.getName(tempReg));  
 \_outputFile << "\t" << opCommand << " " << \_scratchManager.getName(tempReg) << "\n";  
 }  
 else  
 {  
 \_outputFile << "\t" << opCommand << " " << \_scratchManager.getName(tempReg) << "\n";  
 mov(\_scratchManager.getName(reg), \_scratchManager.getName(tempReg));  
 }  
   
 storeMem(varEntry.addr, tempReg);  
   
 \_scratchManager.free(tempReg);  
 node->SetRegister(reg);  
 }  
   
 void CodeGenarator::addressExprCodeGen(NonTerminalNode \*node)  
 {  
 std::string var = ((TerminalNode \*)node->GetChildren()[1])->getToken()->val;  
 std::string addr = getVarAddr(var);  
 int r = \_scratchManager.alloc();  
 \_outputFile << "\tlea " << \_scratchManager.getName(r) << ", " << addr << "\n";  
 node->SetRegister(r);  
 }  
   
 void CodeGenarator::dereferenceExprCodeGen(NonTerminalNode \*node)  
 {  
 int reg = \_scratchManager.alloc();  
 TerminalNode \*idNode = (TerminalNode \*)node->GetChildren()[1];  
   
 string idAddr = getVarAddr(idNode->getToken()->val);  
 loadMemPtrValue(idAddr,reg);  
   
 node->SetRegister(reg);  
 }  
   
 void CodeGenarator::castToFloat(int intReg, int xmmReg)  
 {  
 \_outputFile << "\tcvtsi2ss " << \_scratchManager.getName(xmmReg) << ", " << \_scratchManager.getName(intReg) << "\n";  
 }  
   
 int CodeGenarator::assignStackOffset(scope \*root)  
 {  
 int bytes = layoutLocals(root, 0) + 8; // add rbp  
 if (bytes & 0xF)  
 bytes = (bytes + 15) & ~0xF; // keep 16???byte align  
 return bytes;  
 }  
   
 int CodeGenarator::sizeOfType(const valType &t) const  
 {  
 int base = 8;  
 if (t.type == CHAR)  
 base = 1;  
   
 return base \* t.size; // arrays: len ?? elem  
 }  
   
 string CodeGenarator::nameOfType(const valType &t) const  
 {  
 string res = "QWORD";  
   
 if (t.type == CHAR)  
 res = "BYTE";  
   
 return res;  
 }  
   
 int CodeGenarator::layoutLocals(scope \*s, int offsetSoFar)  
 {  
 for (auto &e : s->getEntries())  
 {  
 int sizeInStack = sizeOfType(e.type);  
 offsetSoFar += sizeInStack;  
 e.addr = nameOfType(e.type) + " ptr [rbp - " + to\_string(offsetSoFar) + "]";  
 e.offset = offsetSoFar;  
 }  
 for (scope \*inner : s->getInnerScopes())  
 offsetSoFar = layoutLocals(inner, offsetSoFar);  
 return offsetSoFar;  
 }  
   
 void CodeGenarator::loadFunctionVariables(functionEntry \*func)  
 {  
 const vector<valType> &params = func->getParamTypes();  
 int startOfParams = 16;  
 int offset = 0;  
 int reg;  
   
 valType currParam;  
 stringstream dstName;  
 stringstream srcName;  
   
 for (size\_t i = 0; i < params.size(); i++)  
 {  
 currParam = params[i];  
 reg = \_scratchManager.alloc();  
   
 srcName << nameOfType(currParam) << " PTR [rbp+" << startOfParams + offset << "]";  
 dstName << nameOfType(currParam) << " PTR [rbp-" << offset + 8 << "]";  
   
 if (currParam.type == FLOAT)  
 reg = \_scratchManager.allocFloat();  
   
 loadFunctionVar(srcName.str(), dstName.str(), reg);  
   
 offset += SIZE\_OF\_STACK\_VAR;  
   
 \_scratchManager.free(reg);  
   
 // clear the string streams  
 srcName.str("");  
 srcName.clear();  
 dstName.str("");  
 dstName.clear();  
 }  
 }  
   
 void CodeGenarator::loadFunctionVar(string srcAddr, string dstAddr, int reg)  
 {  
 loadMem(srcAddr, reg);  
 storeMem(dstAddr, reg);  
 }  
   
 void CodeGenarator::push(int reg)  
 {  
 if (\_scratchManager.isFloat(reg))  
 {  
 \_outputFile << "\tsub rsp, 8\n";  
 \_outputFile << "\tmovsd QWORD PTR [rsp], " << \_scratchManager.getName(reg) << "\n";  
 }  
 else  
 {  
 \_outputFile << "\tpush " << \_scratchManager.getName(reg) << "\n";  
 }  
 }  
   
 void CodeGenarator::mov(string leftReg, string rightReg)  
 {  
 string movCommand = "mov ";  
 if (leftReg.find("xmm") != string::npos)  
 movCommand = "movsd ";  
   
 \_outputFile << "\t" << movCommand << leftReg << ", " << rightReg << "\n";  
 }  
   
   
 void CodeGenarator::neg(int reg)  
 {  
 if (\_scratchManager.isFloat(reg))  
 {  
 // -x ==> 0 - x  
   
 int zeroReg = \_scratchManager.allocFloat();  
 \_outputFile << "xorps " << \_scratchManager.getName(zeroReg) << ", " << \_scratchManager.getName(zeroReg) << "\n";  
 \_outputFile << "\tpsubd " << \_scratchManager.getName(zeroReg) << ", " << \_scratchManager.getName(reg) << "\n";  
 \_outputFile << "\tmovsd " << \_scratchManager.getName(reg) << ", " << \_scratchManager.getName(zeroReg) << "\n";  
 \_scratchManager.free(zeroReg);  
 }  
 else  
 {  
 \_outputFile << "\tneg " << \_scratchManager.getName(reg) << "\n";  
 }  
 }  
   
 void CodeGenarator::compareToZero(int reg)  
 {  
 if (\_scratchManager.isFloat(reg))  
 {  
 int zeroReg = \_scratchManager.allocFloat();  
 \_outputFile << "xorps " << \_scratchManager.getName(zeroReg) << ", " << \_scratchManager.getName(zeroReg) << "\n";  
 \_outputFile << "\tcomisd " << \_scratchManager.getName(reg) << ", " << \_scratchManager.getName(zeroReg) << "\n";  
 \_scratchManager.free(zeroReg);  
 }  
 else  
 {  
 \_outputFile << "\tcmp " << \_scratchManager.getName(reg) << ", 0\n";  
 }  
 }  
   
 void CodeGenarator::loadMemPtrValue(string srcAddr, int reg)  
 {  
 string movCommand = "mov ";  
 string regName = \_scratchManager.getName(reg);  
   
   
 if (srcAddr.find("BYTE") != string::npos)  
 regName = \_scratchManager.getLowerByteName(reg);  
   
   
 \_outputFile << "\t" << "mov " << regName << ", " << srcAddr << "\n";  
 \_outputFile << "\t" << "mov " << regName << ", [" << regName << "]\n";   
 }  
   
 void CodeGenarator::loadMem(string srcAddr, int reg)  
 {  
 string movCommand = "mov ";  
   
 if (\_scratchManager.isFloat(reg))  
 movCommand = "movsd ";  
   
 if (srcAddr.find("BYTE") != string::npos)  
 movCommand = "movzx ";  
   
 \_outputFile << "\t" << movCommand << \_scratchManager.getName(reg) << ", " << srcAddr << "\n";  
 }  
   
 void CodeGenarator::storeMemPtrValue(string srcAddr, int reg)  
 {  
 string movCommand = "mov ";  
 string regName = \_scratchManager.getName(reg);  
   
 if (\_scratchManager.isFloat(reg))  
 movCommand = "movsd ";  
   
 if (srcAddr.find("BYTE") != string::npos)  
 regName = \_scratchManager.getLowerByteName(reg);  
   
 int tempReg = \_scratchManager.alloc();  
 loadMem(srcAddr, tempReg);  
   
 string targetAddr = "QWORD PTR [" + \_scratchManager.getName(tempReg) + "]";  
   
 storeMem(targetAddr, reg);  
 \_scratchManager.free(tempReg);  
 }  
 void CodeGenarator::storeMem(string srcAddr, int reg)  
 {  
 string movCommand = "mov ";  
 string regName = \_scratchManager.getName(reg);  
   
 if (\_scratchManager.isFloat(reg))  
 movCommand = "movsd ";  
   
 if (srcAddr.find("BYTE") != string::npos)  
 regName = \_scratchManager.getLowerByteName(reg);  
   
 \_outputFile << "\t" << movCommand << srcAddr << ", " << regName << "\n";  
 }  
   
 string CodeGenarator::getVarAddr(const string &name) const  
 {  
 scope \*it = \_scopeStack.top();  
 string res = "";  
 while (it)  
 {  
 for (const auto &e : it->getEntries())  
 if (e.name == name && !e.addr.empty())  
 res = e.addr;  
 it = it->getParentScope();  
 }  
   
 return res;  
 }  
   
 void CodeGenarator::printIntFuncCodeGen()  
 {  
 \_outputFile << "function\_printInt:\n";  
 \_outputFile << "\tpush rbp\n";  
 \_outputFile << "\tmov rbp, rsp\n";  
 \_outputFile << "\tsub rsp, 16\n"; // stack space for alignment  
   
 \_outputFile << "\tsub rsp, 32\n"; // shadow space (Windows x64 ABI)  
   
 \_outputFile << "\tmov rdx, QWORD PTR [rbp+16]\n"; // parameter -> rdx  
 \_outputFile << "\tlea rcx, format\_int\n"; // format string -> rcx  
 \_outputFile << "\tcall printf\n";  
   
 \_outputFile << "\tadd rsp, 32\n";  
 \_outputFile << "\tmov eax, 0\n";  
 \_outputFile << "\tmov rsp, rbp\n";  
 \_outputFile << "\tpop rbp\n";  
 \_outputFile << "\tret\n";  
 }  
   
 void CodeGenarator::printFloatFuncCodeGen()  
 {  
 \_outputFile << "function\_printFloat:\n";  
 \_outputFile << "\tpush rbp\n";  
 \_outputFile << "\tmov rbp, rsp\n";  
   
 \_outputFile << "\tsub rsp, 32\n"; // Allocate shadow space for Windows x64 ABI  
   
 \_outputFile << "\tmovsd xmm1, QWORD PTR [rbp+16]\n"; // Move float parameter into xmm1  
 \_outputFile << "\tlea rcx, format\_float\n"; // Load address of format string into rcx  
 \_outputFile << "\tcall printf\n";  
   
 \_outputFile << "\tadd rsp, 32\n";  
 \_outputFile << "\tmov eax, 0\n";  
 \_outputFile << "\tmov rsp, rbp\n";  
 \_outputFile << "\tpop rbp\n";  
 \_outputFile << "\tret\n";  
 }  
   
 void CodeGenarator::floatMacroCodeGen()  
 {  
 \_outputFile << "; Floating-point constant macros\n";  
   
 // 64-bit double macro  
 \_outputFile << "FP8 MACRO value\n";  
 \_outputFile << " LOCAL vname\n";  
 \_outputFile << " .const\n";  
 \_outputFile << " align 8\n";  
 \_outputFile << " vname REAL8 value\n";  
 \_outputFile << " .code\n";  
 \_outputFile << " EXITM <vname>\n";  
 \_outputFile << "ENDM\n\n";  
 }

## codeGen.hpp

#ifndef CODEGEN\_HPP  
 #define CODEGEN\_HPP  
   
 #include <iostream>  
 #include <fstream>  
 #include <vector>  
 #include <stack>  
 #include <string>  
 #include <sstream>  
 #include "../nodes/nodes.hpp"  
 #include "../nodeAnalyzer/nodeAnalyzer.hpp"  
 #include "../symbolTable/symbolTable.hpp"  
 #include "../symbolTable/functionEntry/functionEntry.hpp"  
 #include "../symbolTable/tableEntry/tableEntry.hpp"  
 #include "scratch/scratch.hpp"  
 #include "lableManager/lableManager.hpp"  
 #include <stack>  
 #include <fstream>  
   
 #define NUM\_OF\_BUILT\_IN\_FUNCTIONS 2  
 #define SIZE\_OF\_STACK\_VAR 8  
   
 using namespace std;  
   
 class CodeGenarator  
 {  
 private:  
 ofstream \_outputFile;  
 ASTNode \*\_root;  
 vector<functionEntry \*> \_functions;  
 int \_currFunctionIndex;  
 stack<scope \*> \_scopeStack;  
   
 ScratchManager \_scratchManager;  
 LabelManager \_lableManager;  
   
 functionEntry \*getCurrFunctionEntry() { return \_functions[\_currFunctionIndex]; }  
 int assignStackOffset(scope \*currScope);  
   
 void funcCodeGen(NonTerminalNode \*node);  
 void stmtListCodeGen(NonTerminalNode \*node);  
 void stmtCodeGen(NonTerminalNode \*node);  
 void simpleStmtCodeGen(NonTerminalNode \*node);  
 void varDeclExprCodeGen(NonTerminalNode \*node);  
 void ifStmtCodeGen(NonTerminalNode \*node);  
 void conditionOptionCodeGen(NonTerminalNode \*node);  
 void whileStmtCodeGen(NonTerminalNode \*node);  
 void forStmtCodeGen(NonTerminalNode \*node);  
 void forInitCodeGen(NonTerminalNode \*node);  
 void forUpdateCodeGen(NonTerminalNode \*node);  
 void bodyCodeGen(NonTerminalNode \*node);  
 void assignExpressionCodeGen(NonTerminalNode \*node);  
 void exprOptCodeGen(NonTerminalNode \*node);  
 void exprCodeGen(ASTNode \*node);  
 void addExprCodeGen(NonTerminalNode \*node);  
 void mulExprCodeGen(NonTerminalNode \*node);  
 void unaryExprCodeGen(NonTerminalNode \*node);  
 void primaryExprCodeGen(NonTerminalNode \*node);  
 void callExprCodeGen(NonTerminalNode \*node);  
 void logicalExprCodeGen(NonTerminalNode \*node);  
 void relationalExprCodeGen(NonTerminalNode \*node);  
 void pushArgs(vector<NonTerminalNode \*> args);  
 void incrementExprCodeGen(NonTerminalNode \*node);  
 void addressExprCodeGen(NonTerminalNode \*node);  
 void dereferenceExprCodeGen(NonTerminalNode \*node);  
   
 void castToFloat(int intReg, int xmmReg);  
   
 int sizeOfType(const valType &t) const;  
 string nameOfType(const valType &t) const;  
 int layoutLocals(scope \*s, int runningOffset);  
 void loadFunctionVariables(functionEntry \*func);  
 void loadFunctionVar(string srcAddr, string dstAddr, int reg);  
 void push(int reg);  
 void mov(string leftReg, string rightReg);  
 void neg(int reg);  
 void compareToZero(int reg);  
 void loadMemPtrValue(string srcAddr, int reg);  
 void loadMem(string srcAddr, int reg);  
 void storeMemPtrValue(string srcAddr, int reg);  
 void storeMem(string srcAddr, int reg);  
 string getVarAddr(const string &name) const;  
   
 void printIntFuncCodeGen();  
 void printFloatFuncCodeGen();  
 void floatMacroCodeGen();  
   
 public:  
 CodeGenarator(string outputFile, ASTNode \*root, SymbolTable \*symbolTable);  
 void genCode();  
 };  
   
 #endif

## lableManager.cpp

#include "lableManager.hpp"  
   
 using namespace std;  
   
 LabelManager::LabelManager() : \_lableNum(0) {}  
   
 int LabelManager::create()  
 {  
 return \_lableNum++;  
 }  
   
 string LabelManager::getName(int lableNum)  
 {  
 stringstream res;  
 res << "L" << lableNum;  
 return res.str();  
 }  
   
 string LabelManager::getFunctionLable(string funcName)  
 {  
 return "function\_" + funcName ;  
 }  
   
 string LabelManager::getFunctionPreambleLable(string funcName)  
 {  
 return "function\_" + funcName + "\_preamble";  
 }  
   
 string LabelManager::getFunctionEpilogueLable(string funcName)  
 {  
 return "function\_" + funcName + "\_epilogue";  
 }

## lableManager.hpp

#ifndef \_\_LABLE\_MANAGER  
 #define \_\_LABLE\_MANAGER  
   
 #include <sstream>  
 #include <string>  
   
 using namespace std;  
   
 class LabelManager  
 {  
 private:  
 int \_lableNum;  
   
 public:  
 LabelManager();  
 int create();  
 string getFunctionLable(string funcName);  
 string getFunctionPreambleLable(string funcName);  
 string getFunctionEpilogueLable(string funcName);  
 string getName(int lableNum);  
 };  
   
 #endif

## scratch.cpp

#include "scratch.hpp"  
 #include <iostream>  
   
 using namespace std;  
   
 ScratchManager::ScratchManager()  
 {  
 initRegArr();  
 }  
   
 void ScratchManager::initRegArr()  
 {  
 int regIndex = 0;  
   
 // int/char registers  
 \_regArr[regIndex++] = scratchRegister{"rbx", false};  
 \_regArr[regIndex++] = scratchRegister{"r10", false};  
 \_regArr[regIndex++] = scratchRegister{"r11", false};  
 \_regArr[regIndex++] = scratchRegister{"r12", false};  
 \_regArr[regIndex++] = scratchRegister{"r13", false};  
 \_regArr[regIndex++] = scratchRegister{"r14", false};  
 \_regArr[regIndex++] = scratchRegister{"r15", false};  
   
 // float registers  
 \_regArr[regIndex++] = scratchRegister{"xmm1", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm2", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm3", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm4", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm5", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm6", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm7", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm8", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm9", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm10", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm11", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm12", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm13", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm14", false};  
 \_regArr[regIndex++] = scratchRegister{"xmm15", false};  
 }  
   
 // allocates a new scratch register  
 int ScratchManager::alloc()  
 {  
 int res = -1;  
 for (int i = 0; i < NUM\_OF\_SCRATCH\_REGISTERS; i++)  
 {  
 if (!\_regArr[i].inUse && res == -1)  
 res = i;  
 }  
   
 if (res == -1)  
 {  
 cerr << "Fatal error: out of registers";  
 exit(-1);  
 }  
   
 \_regArr[res].inUse = true;  
 return res;  
 }  
   
 // allocates a new scratch register  
 int ScratchManager::allocFloat()  
 {  
 int res = -1;  
 for (int i = NUM\_OF\_SCRATCH\_REGISTERS; i < NUM\_OF\_SCRATCH\_REGISTERS + NUM\_OF\_FLOAT\_SCRATCH\_REGISTERS; i++)  
 {  
 if (!\_regArr[i].inUse && res == -1)  
 res = i;  
 }  
   
 if (res == -1)  
 {  
 cerr << "Fatal error: out of registers";  
 exit(-1);  
 }  
   
 \_regArr[res].inUse = true;  
 return res;  
 }  
   
 bool ScratchManager::isFloat(int i)  
 {  
 return i >= NUM\_OF\_SCRATCH\_REGISTERS && i < NUM\_OF\_FLOAT\_SCRATCH\_REGISTERS;  
 }  
   
 // frees an occupied register  
 void ScratchManager::free(int i)  
 {  
 if (i >= 0 && i < NUM\_OF\_FLOAT\_SCRATCH\_REGISTERS)  
 \_regArr[i].inUse = false;  
 }  
   
 // returns the name of the register  
 string ScratchManager::getName(int i)  
 {  
 string res;  
   
 if (i >= 0 && i < NUM\_OF\_FLOAT\_SCRATCH\_REGISTERS)  
 res = \_regArr[i].name;  
   
 return res;  
 }  
   
 string ScratchManager::getLowerByteName(int i)  
 {  
 string res = \_regArr[i].name;  
   
 // rbx  
 if (res[1] == 'b')  
 {  
 res = "bl";  
 }  
 else  
 {  
 res = res + "l";  
 }  
   
 return res;  
 }

## scratch.hpp

#ifndef \_\_SCRATCH  
 #define \_\_SCRATCH  
   
 #define NUM\_OF\_SCRATCH\_REGISTERS 7  
 #define NUM\_OF\_FLOAT\_SCRATCH\_REGISTERS 16  
   
 #include <string>  
   
 using namespace std;  
 struct scratchRegister  
 {  
 string name;  
 bool inUse;  
 };  
   
 class ScratchManager  
 {  
 private:  
 scratchRegister \_regArr[NUM\_OF\_SCRATCH\_REGISTERS + NUM\_OF\_FLOAT\_SCRATCH\_REGISTERS];  
 void initRegArr();  
   
 public:  
 ScratchManager();  
 int alloc();  
 int allocFloat();  
 bool isFloat(int i);  
 void free(int i);  
 string getName(int i);  
 string getLowerByteName(int i);  
 bool isAllocated(int i) { return \_regArr[i].inUse; }  
 };  
   
 #endif

## DFA.cpp

#include "../DFA/DFA.hpp"  
 #include <fstream>  
 #include <iomanip>  
 #include <string>  
 using namespace std;  
   
 DFA::DFA(string DFAConfigFile)  
 {  
 \_stateCount = 0;  
   
 ifstream file(DFAConfigFile);  
 string currLine;  
 char TransitionLine[13];  
 stringstream ss;  
 int currentNum;  
 int from;  
 char currSymbol[2];  
 int to;  
   
 if (!file.is\_open())  
 {  
 throw runtime\_error("Failed to open file " + DFAConfigFile);  
 }  
   
 // initialising states  
 getline(file, currLine);  
 ss.clear();  
 ss.str(currLine);  
 ss >> \_stateCount;  
   
 // initialising start state  
 getline(file, currLine);  
 ss.clear();  
 ss.str(currLine);  
 ss >> currentNum;  
 \_startState = currentNum;  
   
 // initialising end states  
 getline(file, currLine);  
 ss.clear();  
 ss.str(currLine);  
   
 while (ss >> currentNum)  
 {  
 \_endStates.push\_back(currentNum);  
 }  
   
 // initialising alphabet  
 int newLineCount = 0;  
 while (file.read(currSymbol, 2) && !(currSymbol[0] == '$' && currSymbol[1] == '$'))  
 {  
 addAlpha(currSymbol[0]);  
 }  
   
 getline(file, currLine);  
   
 // initialising matrix  
 initMatrix();  
   
 // initialising transitions  
 while (file.read(TransitionLine, 12))  
 {  
 TransitionLine[12] = '\0';  
 currLine.assign(TransitionLine);  
 insertTransitionString(currLine);  
 }  
 }  
   
 DFA::DFA(int stateCount, vector<char> \*alphabet)  
 {  
 \_stateCount = stateCount;  
   
 for (char alpha : \*alphabet)  
 {  
 addAlpha(alpha);  
 }  
   
 initMatrix();  
 }  
   
 DFA::DFA() : \_mat(nullptr), \_stateCount(0), \_startState(0) {}  
   
 // adding new symbol to alphabet  
 void DFA::addAlpha(char alpha)  
 {  
 isSymbolExistsErr(alpha, false);  
   
 int nextIndex = \_alphabetToIndex.size();  
 \_alphabetToIndex[alpha] = nextIndex;  
 }  
   
 void DFA::setStateCount(int numOfStates)  
 {  
 if (numOfStates > 0)  
 {  
 \_stateCount = numOfStates;  
 }  
 else  
 {  
 throw runtime\_error("invalid number of states!");  
 }  
 }  
   
 // sets a start state  
 // if the state dosent exists the function throws an error  
 void DFA::setStartState(int state)  
 {  
 isStateExistsWErr(state, true);  
   
 \_startState = state;  
 }  
   
 // returns start state  
 int DFA::getStartState() const  
 {  
 return \_startState;  
 }  
   
 // adding an end state  
 // if the state dosent exists the function throws an error  
 void DFA::addEndState(int state)  
 {  
 //if the number is not a state return an error  
 isStateExistsWErr(state, true);  
   
 \_endStates.push\_back(state);  
 }  
   
 //returns a read only vector of end states  
 const vector<int> &DFA::getEndStates() const  
 {  
 return \_endStates;  
 }  
   
 //returns a vector of the alphabet  
 vector<char> DFA::getAlphabet() const  
 {  
 vector<char> alphabet;  
   
 for (const auto& pair : \_alphabetToIndex) {  
 alphabet.push\_back(pair.first);  
 }  
   
 return alphabet;  
 }  
   
 // initialising an empty dfa sized according to alphabet and number of states  
 void DFA::initMatrix()  
 {  
 int length = \_stateCount;  
 int width = \_alphabetToIndex.size();  
 if (length > 0 && width > 0)  
 {  
 \_mat = new int \*[length];  
 for (int i = 0; i < length; i++)  
 {  
 \_mat[i] = new int[width];  
 }  
   
 // initing all transitions to -1 (trap state)  
 for (int i = 0; i < length; i++)  
 {  
 for (int j = 0; j < width; j++)  
 {  
 \_mat[i][j] = -1;  
 }  
 }  
 }  
 }  
   
 //inserts a new transition to the table  
 //if the transition with (from,alpha) allready exists it overrides it   
 void DFA::insertTransition(int from, char alpha, int to)  
 {   
 isStateExistsWErr(from, true);  
   
 // check if alpha exists in alphabet  
 isSymbolExistsErr(alpha, true);  
   
 // check if the state exists  
 isStateExistsWErr(to, true);  
   
 // adding to the transition matrix  
 int alphaIndex = \_alphabetToIndex[alpha];  
   
 \_mat[from][alphaIndex] = to;  
 }  
   
 void DFA::insertTransitionString(string &transition)  
 {  
 int from;  
 char alpha;  
 int to;  
   
 from = stoi(transition.substr(0, 4)); // convert ascii to int  
 alpha = transition[5];  
 to = stoi(transition.substr(7, 4)); // convert ascii to int  
   
 insertTransition(from, alpha, to);  
 }  
   
 int DFA::getState(int state, char alpha) const  
 {  
 // check if the state exists  
 isStateExistsWErr(state, true);  
   
 // check if alpha exists in alphabet go to trap state  
 if (!isSymbolExists(alpha))  
 return -1;  
   
 int res = \_mat[state][\_alphabetToIndex.at(alpha)];  
   
 return res;  
 }  
   
 // Helper function to check if the state exists, returns an error message if not  
 bool DFA::isStateExsists(int state) const  
 {  
 return state < \_stateCount;  
 }  
   
 // Helper function to check if the symbol exists, returns an error message if not  
 bool DFA::isSymbolExists(char alpha) const  
 {  
 auto alphabetIt = \_alphabetToIndex.find(alpha);  
 return (alphabetIt != \_alphabetToIndex.end());  
 }  
   
 // checks if the state exists and compare the result with the wantedResult  
 // if there is no matching it prints an corresponding error  
 void DFA::isStateExistsWErr(int state, bool wantedResult) const  
 {  
 if (isStateExsists(state) != wantedResult)  
 {  
 stringstream ss;  
 ss << "state " << state << " does not exist!";  
 throw runtime\_error(ss.str());  
 }  
 }  
   
 // checks if the symbol exists and compare the result with the wantedResult  
 // if there is no matching it prints an corresponding error  
 void DFA::isSymbolExistsErr(char alpha, bool wantedResult) const  
 {  
 if (isSymbolExists(alpha) != wantedResult)  
 {  
 stringstream ss;  
 ss << "Symbol " << alpha  
 << (wantedResult ? "does not" : "allready exists")  
 << " in the alphabet!";  
 throw runtime\_error(ss.str());  
 }  
 }  
   
 void DFA::printMatrix() const  
 {  
 unordered\_map<int, char> indexToAlphabet;  
 for (const auto &pair : \_alphabetToIndex)  
 {  
 indexToAlphabet[pair.second] = pair.first; // Reverse key-value  
 }  
   
 // Print the alphabet (column headers)  
 cout << "Symbols: ";  
 for (int i = 0; i < indexToAlphabet.size(); i++)  
 {  
 cout << indexToAlphabet.at(i) <<'\t'<< " ";  
 }  
 cout << endl;  
   
 int length = \_stateCount;  
 int width = \_alphabetToIndex.size();  
 // Print each row (transition for each state)  
 for (int i = 0; i < length; i++)  
 {  
 cout << " State " << i << ": "; // Print the state index at the start of the row  
 for (int j = 0; j < width; j++)  
 {  
 // Print transitions, replacing -1 (trap states) with 'T'  
 if (\_mat[i][j] == -1)  
 {  
 cout << '\t' <<'T';  
 }  
 else  
 {  
 cout << '\t' <<\_mat[i][j];  
 }  
 cout << " ";  
 }  
 cout << endl;  
 }  
 }  
   
 void DFA::writeDFAToFile(string dstFile)  
 {  
 ofstream destf(dstFile);  
   
 if (!destf)  
 {  
 std::cerr << "Error opening file: " << dstFile << std::endl;  
 return;  
 }  
   
 destf << \_stateCount << endl; // write state count  
   
 destf << \_startState << endl; // write start state  
   
 // write end states  
 for (int i = 0; i < \_endStates.size(); i++)  
 {  
 destf << \_endStates[i] << " ";  
 }  
   
 destf << endl;  
   
 // write alphabet  
 unordered\_map<int, char> indexToAlphabet;  
 for (const auto &pair : \_alphabetToIndex)  
 {  
 indexToAlphabet[pair.second] = pair.first; // Reverse key-value  
 }  
   
 for (int i = 0; i < indexToAlphabet.size(); i++)  
 {  
 destf << indexToAlphabet.at(i) << " ";  
 }  
 destf << "$$" << endl;  
   
 // write transitions  
 for (int i = 0; i < \_stateCount; i++)  
 {  
 for (int j = 0; j < indexToAlphabet.size(); j++)  
 {  
 int from = i;  
 char alpha = indexToAlphabet.at(j);  
 int to = getState(from, alpha);  
   
 if (to != -1)  
 {  
 destf << left << setw(4) << setfill(' ') << i << " "  
 << alpha << " "  
 << left << setw(4) << setfill(' ') << getState(i, alpha) << endl;  
 }  
 }  
 }  
   
 destf.close();  
 }  
   
 // checks if a certain word is in the language  
 // returns a pair of values  
 // val 1-> is the word in the language  
 // val 2-> ending state  
 pair<bool, int> DFA::inLanguage(string &word) const  
 {  
 int currState = \_startState;  
 int i = 0;  
   
 while (currState != -1 && i < word.length())  
 {  
 currState = getState(currState, word[i]);  
 i++;  
 }  
   
 bool isInLang = find(\_endStates.begin(), \_endStates.end(), currState) != \_endStates.end();  
 return make\_pair(isInLang, currState);  
 }

## DFA.hpp

#ifndef \_\_DFA  
 #define \_\_DFA  
   
 #include <string>  
 #include <vector>  
 #include <sstream>  
 #include <algorithm>  
 #include <iostream>  
 #include <unordered\_map>  
   
 using namespace std;  
   
 class DFA  
 {  
 private:  
 int \*\*\_mat;  
 int \_stateCount;  
 int \_startState;  
   
 vector<int> \_endStates;  
   
 unordered\_map<char, int> \_alphabetToIndex;  
   
 void isStateExistsWErr(int state, bool wantedResult) const;  
 void isSymbolExistsErr(char alpha, bool wantedResult) const;  
   
 public:  
 DFA(int stateCount, vector<char> \*alphabet);  
 DFA(string DFAConfigFile);  
 DFA();  
 void addAlpha(char alpha);  
 void setStateCount(int numOfStates);  
 void setStartState(int state);  
 int getStartState() const;  
 void addEndState(int state);  
 const vector<int> &getEndStates() const;  
 vector<char> getAlphabet() const;  
 int getState(int state, char alpha) const;  
 void initMatrix();  
 void insertTransition(int from, char alpha, int to);  
 void insertTransitionString(string &transition);  
 bool isStateExsists(int state) const;  
 bool isSymbolExists(const char alpha) const;  
 pair<bool, int> inLanguage(string &word) const;  
 void writeDFAToFile(string dstFile);  
 void printMatrix() const;  
 };  
   
 #endif

## errorHandler.cpp

#include "../errorHandler/errorHandler.hpp"  
   
 int ErrorHandler::getErrorCount() const  
 {  
 return \_errors.size();  
 }  
   
 void ErrorHandler::addError(Error \*error)  
 {  
 \_errors.push\_back(error);  
 }  
   
 void ErrorHandler::printErrors()  
 {  
 for (int i = 0; i < \_errors.size(); i++)  
 {  
 cout << \_errors[i] -> toString() << endl;  
 }  
 }

## errorHandler.hpp

#ifndef \_\_ERROR\_HANDLER  
 #define \_\_ERROR\_HANDLER  
   
 class ErrorHandler;  
   
 #include "../errors/errors.hpp"  
 #include <vector>  
 #include <iostream>  
   
 class ErrorHandler  
 {  
 private:  
 vector<Error\*> \_errors;  
   
 public:  
 ErrorHandler() {}  
   
 int getErrorCount() const;  
   
 void addError(Error \*error);  
   
 void printErrors();  
   
 };  
   
 #endif

## errors.hpp

#ifndef \_\_ERRORS  
 #define \_\_ERRORS  
   
 #include "../token/token.hpp"  
 #include <string>  
 using namespace std;  
   
 class Error  
 {  
 protected:  
 string \_body;  
   
 public:  
 Error(string body) : \_body(body) {}  
 Error() : \_body("") {}  
   
 virtual string toString() const = 0;   
 };  
   
 class SyntaxError : public Error  
 {  
 private:  
 int \_line;  
 int \_column;  
   
 public:  
 SyntaxError(string body, int line, int column) : Error(body), \_line(line), \_column(column) {}  
   
 string toString() const override  
 {  
 return "Syntax Error: " + \_body + " in " + to\_string(\_line) + ":" + to\_string(\_column);  
 }  
 };  
   
 class SyntacticError : public Error  
 {  
 public:  
 SyntacticError(SyntaxToken \* token) {  
 int line = token -> line;  
 int column = token ->column;  
   
 \_body = "unvalid placment of token " + syntaxTokenToString(\*token) + "on" + "{" + to\_string(line) +":" + to\_string(column) + "}\n";  
 }  
   
 SyntacticError(SyntaxToken \* errorToken, SyntaxKind replacment) {  
 int line = errorToken -> line;  
 int column = errorToken ->column;  
   
 \_body = "Parser error on {" + to\_string(line) +":" + to\_string(column) + "} with token " + syntaxTokenToString(\*errorToken) + "\n mabe try using " + syntaxKindToString(replacment) + " instead\n";  
 }  
   
 SyntacticError() {  
 \_body = "broken code structure";  
 }  
   
 string toString() const override  
 {  
 return "SyntaticError: " + \_body;  
 }  
 };  
   
 class semanticError : public Error  
 {  
 public:  
 semanticError(string body) {\_body = body;}  
   
 semanticError(string body, SyntaxToken \* token) {  
 int line = token -> line;  
 int column = token ->column;  
   
 \_body = "semantic error on {" + to\_string(line) +":" + to\_string(column) + "} with token " + syntaxTokenToString(\*token) + "\n" + body;  
 }  
   
 string toString() const override  
 {  
 return "semanticError: " + \_body;  
 }  
   
   
   
 };  
   
 #endif

## lexer.cpp

#include "../lexer/lexer.hpp"  
 #include "../DFA/DFA.hpp"  
 #include "../errors/errors.hpp"  
 #include "../token/token.hpp"  
 #include <string>  
 #include <vector>  
 #include <sstream>  
 #include <algorithm>  
 #include <iostream>  
 #include <fstream>  
   
 // #define LEXER\_DEBUG  
   
 using namespace std;  
   
 SyntaxKind endStateToSyntaxKind[] = {  
 SyntaxKind::UNEXPECTED\_TOKEN, SyntaxKind::INTEGER\_LITERAL, SyntaxKind::FLOAT\_LITERAL, SyntaxKind::CHAR\_LITERAL,  
 SyntaxKind::STRING\_LITERAL, SyntaxKind::IDENTIFIER, SyntaxKind::KEYWORD\_IF,SyntaxKind::KEYWORD\_ELSE,  
 SyntaxKind::KEYWORD\_WHILE, SyntaxKind::KEYWORD\_FOR, SyntaxKind::KEYWORD\_FN,  
 SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT, SyntaxKind::KEYWORD\_CHAR,  
 SyntaxKind::EQUALS, SyntaxKind::COMMA, SyntaxKind::PLUS, SyntaxKind::MINUS,  
 SyntaxKind::SLASH, SyntaxKind::STAR, SyntaxKind::AMPERSAND, SyntaxKind::PIPE,  
 SyntaxKind::CARET, SyntaxKind::TILDE,SyntaxKind::BANG, SyntaxKind::SEMICOLON, SyntaxKind::LESS\_THAN,  
 SyntaxKind::GREATER\_THAN, SyntaxKind::OPEN\_PAREN, SyntaxKind::CLOSED\_PAREN, SyntaxKind::OPEN\_CURLY,  
 SyntaxKind::CLOSED\_CURLY, SyntaxKind::OPEN\_BRACKET, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::RIGHT\_ARROW, SyntaxKind::PLUS\_PLUS, SyntaxKind::MINUS\_MINUS,  
 SyntaxKind::PLUS\_EQUALS, SyntaxKind::MINUS\_EQUALS, SyntaxKind::SLASH\_EQUALS,  
 SyntaxKind::STAR\_EQUALS, SyntaxKind::AMPERSAND\_EQUALS,SyntaxKind::PIPE\_EQUALS, SyntaxKind::CARET\_EQUALS,  
 SyntaxKind::TILDE\_EQUALS, SyntaxKind::EQUALS\_EQUALS, SyntaxKind::LESS\_THAN\_EQUALS,  
 SyntaxKind::GREATER\_THAN\_EQUALS, SyntaxKind::AMPERSAND\_AMPERSAND, SyntaxKind::PIPE\_PIPE,  
 SyntaxKind::BANG\_EQUALS, SyntaxKind::END\_OF\_FILE, SyntaxKind::UNEXPECTED\_TOKEN  
 };  
   
 Lexer::Lexer(string srcFile, string DFAConfigFile, ErrorHandler \*handler)  
 : \_srcFile(srcFile), \_dfa(DFAConfigFile), \_errorHandler(handler), \_cursor(0), \_currLine(1), \_currColumn(1)  
 {  
 ifstream src(\_srcFile);  
   
 src.seekg(0, ios::end);  
 \_fileSize = src.tellg();  
 src.close();  
 }  
   
 vector<SyntaxToken \*> Lexer::getTokens()  
 {  
 vector<SyntaxToken \*> tokens;  
 SyntaxToken \*currToken;  
   
 while ((currToken = getNextToken())->kind != SyntaxKind::END\_OF\_FILE)  
 {  
 tokens.push\_back(currToken);  
 }  
   
 tokens.push\_back(currToken); // pushing the EOF token  
   
 #ifdef LEXER\_DEBUG  
 for (int i = 0; i < tokens.size(); i++)  
 {  
 cout << syntaxTokenToString(\*tokens[i]) << endl;  
 }  
 #endif   
   
 return tokens;  
 }  
   
 SyntaxToken \*Lexer::getNextToken()  
 {  
 char currentChar;  
 stringstream val;  
 int currentState = \_dfa.getStartState();  
 int prevState;  
 SyntaxToken \*resToken = new SyntaxToken();  
 ifstream src(\_srcFile);  
 src.seekg(\_cursor, ios::beg);  
   
 if (\_cursor >= \_fileSize)  
 {  
 resToken->kind = SyntaxKind::END\_OF\_FILE;  
 return resToken;  
 }  
   
 if (!src.is\_open())  
 {  
 runtime\_error("Error: Unable to open sorce file");  
 return resToken;  
 }  
   
 do  
 {  
 // get the next character  
 src.get(currentChar);  
 \_cursor++;  
   
 // get the corresponding next state  
 prevState = currentState;  
 currentState = \_dfa.getState(currentState, currentChar);  
   
 // if we didnt finish lexing the token, recognize it.  
 if (currentState != -1 && \_cursor <= \_fileSize)  
 {  
 val << currentChar;  
 }  
   
 // if we dident pocess the token, update the position  
 if (currentState != -1 || prevState == \_dfa.getStartState())  
 {  
 updatePosition(currentChar);  
 }  
   
 } while (currentState != -1 && \_cursor <= \_fileSize);  
   
 \_cursor--;  
 currentState = prevState;  
 src.close();  
   
 // if the state is a skip state, take the token after it  
 if (isSkipState(currentState))  
 {  
 delete resToken;  
 resToken = getNextToken();  
 }  
 else  
 {  
 // else if the state is an end state, return the token  
 resToken->line = \_currLine;  
 resToken->column = \_currColumn;  
   
 vector<int> endStates = \_dfa.getEndStates();  
 if (find(endStates.begin(), endStates.end(), currentState) != endStates.end())  
 {  
 resToken->kind = getSyntaxKind(currentState);  
 resToken->val = val.str();  
 }  
   
 // else the token is invalid so return an unexpected token  
 else  
 {  
 // if the token is invalid, add an error to the handler and skip it  
 \_cursor++;  
 resToken->kind = SyntaxKind::UNEXPECTED\_TOKEN;  
 \_errorHandler->addError(new SyntaxError("Unexpected token error", \_currLine, \_currColumn));  
 }  
 }  
   
   
 return resToken;  
 }  
   
 void Lexer::updatePosition(char ch)  
 {  
 if (ch == '\t')  
 {  
 \_currColumn += 4; // (tab is 4 spaces)  
 }  
 else if (ch == 0x0A)  
 {  
 \_currColumn = 0;  
 \_currLine++;  
   
 \_cursor++; // skip the carriage return in the src code  
 }  
 else if (ch != 0x0D) // Skip carriage return characters  
 {  
 \_currColumn++;  
 }  
 }  
   
 // print & print helper funcs:  
 SyntaxKind getSyntaxKind(int state)  
 {  
 if (state < SyntaxKind::UNEXPECTED\_TOKEN)  
 return endStateToSyntaxKind[state];  
   
 return SyntaxKind::IDENTIFIER;  
 }  
   
 void Lexer::printTransitionMatrix() const  
 {  
 \_dfa.printMatrix();  
 }  
   
 bool isSkipState(int state)  
 {  
 return state == NUM\_OF\_STATES - 1 || state == NUM\_OF\_STATES - 2;  
 }  
   
 bool isWhitespace(char ch)  
 {  
 return ch == ' ' || ch == '\n' || ch == '\t' || ch == '\r';  
 }

## lexer.hpp

#ifndef \_\_LEXER  
 #define \_\_LEXER  
   
 struct SyntaxToken;  
   
 #include "../DFA/DFA.hpp"  
 #include "../errorHandler/errorHandler.hpp"  
 #include "../errors/errors.hpp"  
 #include "../token/token.hpp"  
 #include "../parser/grammerSymbol/grammerSymbol.hpp"  
 #include <string>  
 #include <vector>  
 #include <sstream>  
   
 using namespace std;  
   
 #define NUM\_OF\_STATES 107  
   
 extern SyntaxKind endStateToSyntaxKind[];  
   
 class Lexer  
 {  
 private:  
 string \_srcFile;  
 DFA \_dfa;  
 int \_cursor;  
 int \_fileSize;  
   
 ErrorHandler \*\_errorHandler;  
   
 int \_currLine;  
 int \_currColumn;  
   
 public:  
 Lexer(string srcFile, string DFAConfigFile, ErrorHandler \*handler);  
 vector<SyntaxToken \*> getTokens();  
 SyntaxToken \*getNextToken();  
 void updatePosition(char ch);  
 void printTransitionMatrix() const;  
 };  
   
 SyntaxKind getSyntaxKind(int state);  
 string syntaxTokenToString(SyntaxToken token);  
 bool isSkipState(int state);  
 bool isWhitespace(char ch);  
 #endif

## main.cpp

#include "../lexer/lexer.hpp"  
 #include "../token/token.hpp"  
 #include "../errorHandler/errorHandler.hpp"  
 #include "../parser/parser.hpp"  
 #include "../semantic/semantic.hpp"  
 #include "../codeGenarator/codeGen.hpp"  
 #include <string>  
 #include <sstream>  
 #include <iostream>  
 #include <fstream>  
   
 using namespace std;  
 string getFileBaseName(string fileName);  
   
 int main(int argc, char \*\*argv)  
 {  
 string filePath;  
   
 if (argc != 2)  
 {  
 cout << "ERROR: Please enter the input file";  
 return 1;  
 }  
   
 filePath = argv[1];  
 string baseName = getFileBaseName(filePath);  
   
 ErrorHandler errorHandler;  
 SymbolTable symbolTable;  
 Lexer lex(filePath, "..\\src\\lexerDFAConfig.txt", &errorHandler);  
 vector<SyntaxToken \*> tokens = lex.getTokens();  
   
 if (errorHandler.getErrorCount() > 0)  
 {  
 errorHandler.printErrors();  
 }  
 else  
 {  
 SemanticAnalyzer semantic(&errorHandler, &symbolTable);  
 Parser parser(tokens, 185, &errorHandler, &semantic);  
   
 ASTNode \*root = parser.parse();  
   
 if (errorHandler.getErrorCount() > 0)  
 {  
 cout << "Parsing failed with errors!" << endl;  
 errorHandler.printErrors();  
 }  
 else  
 {  
 cout << "Parsing completed successfully!" << endl;  
 cout << "Generating code to " << baseName << ".asm" << endl;  
 CodeGenarator codeGen(baseName + ".asm", root, &symbolTable);  
 codeGen.genCode();  
 }  
   
 cout << "compiling finished!";  
 }  
 }  
   
 string getFileBaseName(string fileName)  
 {  
   
 size\_t lastSlash = fileName.find\_last\_of("\\/");  
 if (lastSlash == string::npos)  
 lastSlash = -1;  
   
 size\_t lastDot = fileName.find\_last\_of('.');  
 if (lastDot == string::npos)  
 lastDot = fileName.length();  
   
 string baseName = fileName.substr(lastSlash + 1, lastDot - lastSlash - 1);  
   
 return baseName;  
 }

## nodeAnalyzer.cpp

#include "nodeAnalyzer.hpp"  
 #include <algorithm>  
   
 bool isFuncCall(ASTNode \*node)  
 {  
 bool res = false;  
   
 if (node->GetType() == NON\_TERMINAL)  
 {  
 NonTerminalNode \*ntNode = ((NonTerminalNode \*)node);  
 if (ntNode->getNonTerminalKind() == PRIMARY\_EXPR || ntNode->getNonTerminalKind() == SIMPLE\_STMT)  
 {  
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 if (children.size() == 4)  
 {  
 if (((TerminalNode \*)children[1])->getTerminalKind() == OPEN\_PAREN)  
 res = true;  
 }  
 }  
 }  
   
 return res;  
 }  
   
   
 bool isArrDeref(ASTNode \*node)  
 {  
 bool res = false;  
   
 if (node->GetType() == NON\_TERMINAL)  
 {  
 NonTerminalNode \*ntNode = ((NonTerminalNode \*)node);  
 if (ntNode->getNonTerminalKind() == PRIMARY\_EXPR)  
 {  
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 if (children.size() == 4)  
 {  
 if (((TerminalNode \*)children[1])->getTerminalKind() == OPEN\_BRACKET)  
 res = true;  
 }  
 }  
 }  
   
 return res;  
 }  
   
 bool isReturnStatement(ASTNode \*node)  
 {  
 bool res = false;  
   
 if (node->GetType() == NON\_TERMINAL)  
 {  
 NonTerminalNode \*ntNode = ((NonTerminalNode \*)node);  
 if (ntNode->getNonTerminalKind() == SIMPLE\_STMT)  
 {  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 if (children.size() == 2)  
 {  
 res = true;  
 }  
 }  
 }  
   
 return res;  
 }  
   
 void getFunctionParamNodesHelper(NonTerminalNode \*paramListNonEmptyNode, vector<NonTerminalNode \*> \*paramNodes)  
 {  
 vector<ASTNode \*> childern = paramListNonEmptyNode->GetChildren();  
 int numOfChildren = childern.size();  
   
 NonTerminalNode \*paramNode;  
 if (numOfChildren == 1)  
 {  
 paramNode = ((NonTerminalNode \*)(childern[0]));  
 paramNodes->push\_back(paramNode);  
 }  
   
 if (numOfChildren == 3)  
 {  
 paramNode = ((NonTerminalNode \*)(childern[2]));  
 paramNodes->push\_back(paramNode);  
 getFunctionParamNodesHelper((NonTerminalNode \*)childern[0], paramNodes);  
 }  
 }  
   
 int getExprListNonEmptySize(NonTerminalNode \*exprListNonEmptyNode)  
 {  
 vector<ASTNode \*> childern = exprListNonEmptyNode->GetChildren();  
 int numOfChildren = childern.size();  
   
 int res = 0;  
   
 if (numOfChildren == 1)  
 {  
 res = 1;  
 }  
   
 if (numOfChildren == 3)  
 {  
 res = 1 + getExprListNonEmptySize((NonTerminalNode \*)childern[0]);  
 }  
   
 return 0;  
 }  
   
 vector<NonTerminalNode \*> getFunctionParamNodes(NonTerminalNode \*paramListNode)  
 {  
 vector<ASTNode \*> childern = paramListNode->GetChildren();  
 vector<NonTerminalNode \*> res;  
   
 if (childern.size() > 0)  
 {  
 getFunctionParamNodesHelper((NonTerminalNode \*)childern[0], &res);  
 }  
   
 std::reverse(res.begin(), res.end());  
 return res;  
 }  
   
 void getFunctionCallArgsNodesHelper(NonTerminalNode \*exprListNonEmptyNode, vector<NonTerminalNode \*> \*exprNodes)  
 {  
 vector<ASTNode \*> childern = exprListNonEmptyNode->GetChildren();  
 int numOfChildren = childern.size();  
   
 NonTerminalNode \*exprNode;  
 if (numOfChildren == 1)  
 {  
 exprNode = ((NonTerminalNode \*)(childern[0]));  
 exprNodes->push\_back(exprNode);  
 }  
   
 if (numOfChildren == 3)  
 {  
 exprNode = ((NonTerminalNode \*)(childern[2]));  
 exprNodes->push\_back(exprNode);  
 getFunctionCallArgsNodesHelper((NonTerminalNode \*)childern[0], exprNodes);  
 }  
 }  
   
 vector<NonTerminalNode \*> getFunctionCallArgsNodes(NonTerminalNode \*exprListNode)  
 {  
 vector<ASTNode \*> childern = exprListNode->GetChildren();  
 vector<NonTerminalNode \*> res;  
   
 if (childern.size() > 0)  
 {  
 getFunctionParamNodesHelper((NonTerminalNode \*)childern[0], &res);  
 }  
   
 std::reverse(res.begin(), res.end());  
 return res;  
 }  
   
 void getFunctionDeclNodesHelper(NonTerminalNode \*programNode, vector<NonTerminalNode \*> \*funcDeclNodes)  
 {  
 const vector<ASTNode \*> &children = programNode->GetChildren();  
   
 if (children.size() == 2)  
 {  
 funcDeclNodes->push\_back((NonTerminalNode \*)children[1]);  
 getFunctionDeclNodesHelper((NonTerminalNode \*)children[0], funcDeclNodes);  
 }  
 }  
   
 vector<NonTerminalNode \*> getFunctionDeclNodes(NonTerminalNode \*programNode)  
 {  
 vector<NonTerminalNode \*> res;  
 if (!programNode->GetChildren().empty())  
 {  
 getFunctionDeclNodesHelper(programNode, &res);  
 }  
   
 std::reverse(res.begin(), res.end());  
 return res;  
 }  
   
 void getStmtNodesHelper(NonTerminalNode \*stmtListNonEmptyNode, vector<NonTerminalNode \*> \*stmtNodes)  
 {  
 const vector<ASTNode \*> &children = stmtListNonEmptyNode->GetChildren();  
   
 if (children.size() == 2)  
 {  
 stmtNodes->push\_back((NonTerminalNode \*)children[1]);  
 getStmtNodesHelper((NonTerminalNode \*)children[0], stmtNodes);  
 }  
 }  
   
 vector<NonTerminalNode \*> getStmtNodes(NonTerminalNode \*stmtListNode)  
 {  
 vector<NonTerminalNode \*> res;  
 if (!stmtListNode->GetChildren().empty())  
 {  
 getStmtNodesHelper(stmtListNode, &res);  
 }  
   
 std::reverse(res.begin(), res.end());  
 return res;  
 }

## nodeAnalyzer.hpp

#ifndef \_\_NODE\_ANALYZER  
 #define \_\_NODE\_ANALYZER  
   
 #include "../nodes.hpp"  
 #include "../../parser/grammerSymbol/grammerSymbol.hpp"  
 #include "../../token/token.hpp"  
   
 bool isFuncCall(ASTNode \*node);  
 bool isArrDeref(ASTNode \*node);  
 bool isReturnStatement(ASTNode \*node);  
 int getExprListNonEmptySize(NonTerminalNode \*exprListNode);  
 vector<NonTerminalNode \*> getFunctionParamNodes(NonTerminalNode \*paramListNode);  
 vector<NonTerminalNode \*> getFunctionCallArgsNodes(NonTerminalNode \*paramListNode);  
 vector<NonTerminalNode \*> getFunctionDeclNodes(NonTerminalNode \*programNode);  
 vector<NonTerminalNode \*> getStmtNodes(NonTerminalNode \*stmtListNode);  
   
 #endif

## nodes.cpp

#include "Nodes.hpp"  
 #include "../token/token.hpp"  
 #include "../parser/grammerSymbol/grammerSymbol.hpp"  
 #include <vector>  
 #include <string>  
   
 using namespace std;  
   
 TerminalNode::TerminalNode(SyntaxToken \*token) : \_token(token)  
 {  
 \_syntaxKind = token->kind;  
 \_type = GrammarSymbolType::TERMINAL;  
 }  
   
 SyntaxKind TerminalNode::getTerminalKind() const  
 {  
 return \_syntaxKind;  
 }  
   
 SyntaxToken \*TerminalNode::getToken() const  
 {  
 return \_token;  
 }  
   
 const vector<ASTNode \*> &TerminalNode::GetChildren() const  
 {  
 static const vector<ASTNode \*> empty;  
 return empty;  
 }  
   
 //--------------------------------non terminal node--------------------------------  
   
 NonTerminalNode::NonTerminalNode(NonTerminal nonTerminalKind)  
 : \_nonTerminalKind(nonTerminalKind), \_children()  
 {  
 \_type = GrammarSymbolType::NON\_TERMINAL;  
 }  
   
 void NonTerminalNode::AddChildToEnd(ASTNode \*child)  
 {  
 \_children.push\_back(child);  
 }  
   
 void NonTerminalNode::AddChildToFront(ASTNode \*child)  
 {  
 \_children.insert(\_children.begin(), child);  
 }  
   
 NonTerminal NonTerminalNode::getNonTerminalKind() const  
 {  
 return \_nonTerminalKind;  
 }  
   
 const std::vector<ASTNode \*> &NonTerminalNode::GetChildren() const  
 {  
 return \_children;  
 }  
   
 //--------------------------------debugging--------------------------------  
   
 string AstNodeToString(ASTNode \*node)  
 {  
 string res = "";  
   
 if (node->GetType() == GrammarSymbolType::TERMINAL)  
 {  
 res = syntaxTokenToString(\*((TerminalNode \*)node)->getToken());  
 }  
 else  
 {  
 res = nonTerminalToString(((NonTerminalNode \*)node)->getNonTerminalKind());  
 }  
   
 res += " (";  
 res += valTypeToString(node->GetValType());  
 res += ")";  
   
 return res;  
 }  
   
 void printAstNode(ASTNode \*node)  
 {  
 cout << AstNodeToString(node) << endl;  
 }  
   
 void PrintParseTree(ASTNode \*node)  
 {  
 PrintParseTreeHelper(node,"",true);  
 }  
   
 void PrintParseTreeHelper(ASTNode \*parent, const string &prefix, bool isLast)  
 {  
 if (parent == nullptr)  
 {  
 return;  
 }  
   
 cout << prefix;  
   
 cout << (isLast ? "|\_\_ " : "|-- ") << AstNodeToString(parent) << endl;  
   
 vector<ASTNode \*> children = parent->GetChildren();  
   
 int childernCount = children.size();  
   
 for (int i = 0; i < childernCount; i++)  
 {  
 string newPrefix = prefix + (isLast ? " " : "| ");  
 PrintParseTreeHelper(children.at(i), newPrefix, i == childernCount - 1);  
 }  
 }

## nodes.hpp

#ifndef \_\_NODES  
 #define \_\_NODES  
   
 #include "../token/token.hpp"  
 #include "../parser/grammerSymbol/grammerSymbol.hpp"  
 #include "../symbolTable/tableEntry/tableEntry.hpp"  
 #include <vector>  
 #include <string>  
 #include <iostream>  
   
 using namespace std;  
   
 class ASTNode  
 {  
 protected:  
 GrammarSymbolType \_type;  
 valType \_valType; //be used for semantic analysis  
 int \_register; //be used for code gen phase   
   
 public:  
 const GrammarSymbolType GetType() const  
 {  
 return \_type;  
 }  
   
 const valType GetValType() const  
 {  
 return \_valType;  
 }  
   
 void SetValType(valType valType)  
 {  
 \_valType = valType;  
 }  
   
 int GetRegister() const  
 {  
 return \_register;  
 }  
   
 void SetRegister(int regIndex)  
 {  
 \_register = regIndex;  
 }  
   
 const virtual vector<ASTNode \*> &GetChildren() const = 0;  
 };  
   
 class TerminalNode : public ASTNode  
 {  
 private:  
 SyntaxKind \_syntaxKind;  
 SyntaxToken \*\_token;  
   
 public:  
 TerminalNode(SyntaxToken \*token);  
   
 SyntaxKind getTerminalKind() const;  
 SyntaxToken \*getToken() const;  
 const vector<ASTNode \*> &GetChildren() const override;  
 };  
   
 class NonTerminalNode : public ASTNode  
 {  
 private:  
 NonTerminal \_nonTerminalKind;  
 vector<ASTNode \*> \_children;  
   
 public:  
 NonTerminalNode(NonTerminal nonTerminalKind);  
   
 void AddChildToFront(ASTNode \*child);  
 void AddChildToEnd(ASTNode \*child);  
   
 NonTerminal getNonTerminalKind() const;  
 const std::vector<ASTNode \*> &GetChildren() const override;  
 };  
   
 string AstNodeToString(ASTNode \*node);  
 void printAstNode(ASTNode \*node);  
 void PrintParseTree(ASTNode \*parent);  
 void PrintParseTreeHelper(ASTNode \*parent, const std::string &prefix, bool isLast);  
 #endif

## grammerSymbol.cpp

#include "grammerSymbol.hpp"  
 #include <string>  
 #include <sstream>  
   
 using namespace std;  
   
 string nonTerminalEnumToString[] = {  
 "START",  
 "PROGRAM",  
 "FUNCTION\_DECL",  
 "PARAM\_LIST",  
 "PARAM\_LIST\_NON\_EMPTY",  
 "PARAM",  
 "TYPE",  
 "BASE\_TYPE",  
 "STMT\_LIST",  
 "STMT",  
 "SIMPLE\_STMT",  
 "VAR\_DECL\_EXPR",  
 "INIT\_OPT",  
 "ASSIGN\_VALUE",  
 "ASSIGN\_EXPR",  
 "ASSIGN\_TARGET",  
 "ASSIGN\_OP",  
 "IF\_STMT",  
 "WHILE\_STMT",  
 "CONDITION\_OP",  
 "FOR\_STMT",  
 "FOR\_INIT",  
 "EXPR\_OPT",  
 "FOR\_UPDATE",  
 "BODY",  
 "EXPR\_LIST",  
 "EXPR\_LIST\_NON\_EMPTY",  
 "EXPR",  
 "LOGICAL\_EXPR",  
 "RELATIONAL\_EXPR",  
 "ADD\_EXPR",  
 "MUL\_EXPR",  
 "UNARY\_EXPR",  
 "INCREMENT\_EXPR",  
 "ADDRESS\_EXPR",  
 "DEREFERENCE\_EXPR",  
 "PRIMARY\_EXPR"  
 };  
   
   
 string nonTerminalToString(NonTerminal kind)  
 {  
 stringstream res;  
 res << "\e[1;34m<"  
 << nonTerminalEnumToString[(int)kind]  
 << ">\033[0m";  
   
 return res.str();  
 }

## grammerSymbol.hpp

#ifndef \_\_GAMMER\_SYMBOL  
 #define \_\_GAMMER\_SYMBOL  
   
 #include <string>  
   
 using namespace std;  
   
 enum GrammarSymbolType  
 {  
 TERMINAL,  
 NON\_TERMINAL  
 };  
   
 enum NonTerminal  
 {  
 START,  
 PROGRAM,  
 FUNCTION\_DECL,  
 PARAM\_LIST,  
 PARAM\_LIST\_NON\_EMPTY,  
 PARAM,  
 TYPE,  
 BASE\_TYPE,  
 STMT\_LIST,  
 STMT,  
 SIMPLE\_STMT,  
 VAR\_DECL\_EXPR,  
 INIT\_OPT,  
 ASSIGN\_VALUE,  
 ASSIGN\_EXPR,  
 ASSIGN\_TARGET,  
 ASSIGN\_OP,  
 IF\_STMT,  
 WHILE\_STMT,  
 CONDITION\_OP,  
 FOR\_STMT,  
 FOR\_INIT,  
 EXPR\_OPT,  
 FOR\_UPDATE,  
 BODY,  
 EXPR\_LIST,  
 EXPR\_LIST\_NON\_EMPTY,  
 EXPR,  
 LOGICAL\_EXPR,  
 RELATIONAL\_EXPR,  
 ADD\_EXPR,  
 MUL\_EXPR,  
 UNARY\_EXPR,  
 INCREMENT\_EXPR,  
 ADDRESS\_EXPR,  
 DEREFERENCE\_EXPR,  
 PRIMARY\_EXPR,  
 NON\_TERMINAL\_COUNT  
 };  
   
   
 string nonTerminalToString(NonTerminal kind);  
   
 #endif

## initParserFunctions.cpp

#include "parser.hpp"  
 #include "productionRule/productionRule.hpp"  
 #include "../token/token.hpp"  
 void Parser::initProductionRules()  
 {  
 productionRule rule;  
   
 // Rule 0: $accept -> Program $end  
 rule.setLeft(START);  
 rule.addSymbol(PROGRAM).addSymbol(END\_OF\_FILE);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 1: Program -> ??  
 rule.setLeft(PROGRAM);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 2: Program -> Program FunctionDecl  
 rule.setLeft(PROGRAM);  
 rule.addSymbol(PROGRAM).addSymbol(FUNCTION\_DECL);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 3: FunctionDecl -> KEYWORD\_FN IDENTIFIER OPEN\_PAREN ParamList CLOSED\_PAREN RIGHT\_ARROW Type OPEN\_CURLY StmtList CLOSED\_CURLY  
 rule.setLeft(FUNCTION\_DECL);  
 rule.addSymbol(KEYWORD\_FN).addSymbol(IDENTIFIER).addSymbol(OPEN\_PAREN)  
 .addSymbol(PARAM\_LIST).addSymbol(CLOSED\_PAREN).addSymbol(RIGHT\_ARROW)  
 .addSymbol(TYPE).addSymbol(OPEN\_CURLY).addSymbol(STMT\_LIST).addSymbol(CLOSED\_CURLY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 4: ParamList -> ??  
 rule.setLeft(PARAM\_LIST);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 5: ParamList -> ParamListNonEmpty  
 rule.setLeft(PARAM\_LIST);  
 rule.addSymbol(PARAM\_LIST\_NON\_EMPTY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 6: ParamListNonEmpty -> Param  
 rule.setLeft(PARAM\_LIST\_NON\_EMPTY);  
 rule.addSymbol(PARAM);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 7: ParamListNonEmpty -> ParamListNonEmpty COMMA Param  
 rule.setLeft(PARAM\_LIST\_NON\_EMPTY);  
 rule.addSymbol(PARAM\_LIST\_NON\_EMPTY).addSymbol(COMMA).addSymbol(PARAM);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 8: Param -> Type IDENTIFIER  
 rule.setLeft(PARAM);  
 rule.addSymbol(TYPE).addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 9: Type -> BaseType  
 rule.setLeft(TYPE);  
 rule.addSymbol(BASE\_TYPE);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 10: Type -> BaseType OPEN\_BRACKET INTEGER\_LITERAL CLOSED\_BRACKET  
 rule.setLeft(TYPE);  
 rule.addSymbol(BASE\_TYPE).addSymbol(OPEN\_BRACKET).addSymbol(INTEGER\_LITERAL).addSymbol(CLOSED\_BRACKET);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 11: Type -> BaseType STAR  
 rule.setLeft(TYPE);  
 rule.addSymbol(BASE\_TYPE).addSymbol(STAR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 12: BaseType -> KEYWORD\_INT  
 rule.setLeft(BASE\_TYPE);  
 rule.addSymbol(KEYWORD\_INT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 13: BaseType -> KEYWORD\_FLOAT  
 rule.setLeft(BASE\_TYPE);  
 rule.addSymbol(KEYWORD\_FLOAT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 14: BaseType -> KEYWORD\_CHAR  
 rule.setLeft(BASE\_TYPE);  
 rule.addSymbol(KEYWORD\_CHAR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 15: StmtList -> ??  
 rule.setLeft(STMT\_LIST);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 16: StmtList -> StmtList Stmt  
 rule.setLeft(STMT\_LIST);  
 rule.addSymbol(STMT\_LIST).addSymbol(STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 17: Stmt -> SimpleStmt SEMICOLON  
 rule.setLeft(STMT);  
 rule.addSymbol(SIMPLE\_STMT).addSymbol(SEMICOLON);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 18: Stmt -> OPEN\_CURLY StmtList CLOSED\_CURLY  
 rule.setLeft(STMT);  
 rule.addSymbol(OPEN\_CURLY).addSymbol(STMT\_LIST).addSymbol(CLOSED\_CURLY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 19: Stmt -> IfStmt  
 rule.setLeft(STMT);  
 rule.addSymbol(IF\_STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 20: Stmt -> WhileStmt  
 rule.setLeft(STMT);  
 rule.addSymbol(WHILE\_STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 21: Stmt -> ForStmt  
 rule.setLeft(STMT);  
 rule.addSymbol(FOR\_STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 22: SimpleStmt -> VarDeclExpr  
 rule.setLeft(SIMPLE\_STMT);  
 rule.addSymbol(VAR\_DECL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 23: SimpleStmt -> AssignExpr  
 rule.setLeft(SIMPLE\_STMT);  
 rule.addSymbol(ASSIGN\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 24: SimpleStmt -> IDENTIFIER OPEN\_PAREN ExprList CLOSED\_PAREN  
 rule.setLeft(SIMPLE\_STMT);  
 rule.addSymbol(IDENTIFIER).addSymbol(OPEN\_PAREN).addSymbol(EXPR\_LIST).addSymbol(CLOSED\_PAREN);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 25: SimpleStmt -> KEYWORD\_RET ExprOpt  
 rule.setLeft(SIMPLE\_STMT);  
 rule.addSymbol(KEYWORD\_RET).addSymbol(EXPR\_OPT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 26: VarDeclExpr -> Type IDENTIFIER InitOpt  
 rule.setLeft(VAR\_DECL\_EXPR);  
 rule.addSymbol(TYPE).addSymbol(IDENTIFIER).addSymbol(INIT\_OPT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 27: InitOpt -> ??  
 rule.setLeft(INIT\_OPT);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 28: InitOpt -> EQUALS AssignValue  
 rule.setLeft(INIT\_OPT);  
 rule.addSymbol(EQUALS).addSymbol(ASSIGN\_VALUE);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 29: AssignValue -> Expr  
 rule.setLeft(ASSIGN\_VALUE);  
 rule.addSymbol(EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 30: AssignValue -> OPEN\_CURLY ExprList CLOSED\_CURLY  
 rule.setLeft(ASSIGN\_VALUE);  
 rule.addSymbol(OPEN\_CURLY).addSymbol(EXPR\_LIST).addSymbol(CLOSED\_CURLY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 31: AssignExpr -> AssignTarget AssignOp Expr  
 rule.setLeft(ASSIGN\_EXPR);  
 rule.addSymbol(ASSIGN\_TARGET).addSymbol(ASSIGN\_OP).addSymbol(EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 32: AssignTarget -> IDENTIFIER  
 rule.setLeft(ASSIGN\_TARGET);  
 rule.addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 33: AssignTarget -> IDENTIFIER OPEN\_BRACKET Expr CLOSED\_BRACKET  
 rule.setLeft(ASSIGN\_TARGET);  
 rule.addSymbol(IDENTIFIER).addSymbol(OPEN\_BRACKET).addSymbol(EXPR).addSymbol(CLOSED\_BRACKET);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 34: AssignTarget -> STAR IDENTIFIER  
 rule.setLeft(ASSIGN\_TARGET);  
 rule.addSymbol(STAR).addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 35: AssignOp -> EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 36: AssignOp -> PLUS\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(PLUS\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 37: AssignOp -> MINUS\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(MINUS\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 38: AssignOp -> SLASH\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(SLASH\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 39: AssignOp -> STAR\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(STAR\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 40: AssignOp -> AMPERSAND\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(AMPERSAND\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 41: AssignOp -> PIPE\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(PIPE\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 42: AssignOp -> CARET\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(CARET\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 43: AssignOp -> TILDE\_EQUALS  
 rule.setLeft(ASSIGN\_OP);  
 rule.addSymbol(TILDE\_EQUALS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 44: IfStmt -> KEYWORD\_IF OPEN\_PAREN ConditionOp CLOSED\_PAREN Body  
 rule.setLeft(IF\_STMT);  
 rule.addSymbol(KEYWORD\_IF).addSymbol(OPEN\_PAREN).addSymbol(CONDITION\_OP)  
 .addSymbol(CLOSED\_PAREN).addSymbol(BODY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 45: IfStmt -> KEYWORD\_IF OPEN\_PAREN ConditionOp CLOSED\_PAREN Body KEYWORD\_ELSE Body  
 rule.setLeft(IF\_STMT);  
 rule.addSymbol(KEYWORD\_IF).addSymbol(OPEN\_PAREN).addSymbol(CONDITION\_OP)  
 .addSymbol(CLOSED\_PAREN).addSymbol(BODY).addSymbol(KEYWORD\_ELSE).addSymbol(BODY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 46: WhileStmt -> KEYWORD\_WHILE OPEN\_PAREN ConditionOp CLOSED\_PAREN Body  
 rule.setLeft(WHILE\_STMT);  
 rule.addSymbol(KEYWORD\_WHILE).addSymbol(OPEN\_PAREN).addSymbol(CONDITION\_OP)  
 .addSymbol(CLOSED\_PAREN).addSymbol(BODY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 47: ConditionOp -> Expr  
 rule.setLeft(CONDITION\_OP);  
 rule.addSymbol(EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 48: ConditionOp -> AssignExpr  
 rule.setLeft(CONDITION\_OP);  
 rule.addSymbol(ASSIGN\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 49: ForStmt -> KEYWORD\_FOR OPEN\_PAREN ForInit SEMICOLON ExprOpt SEMICOLON ForUpdate CLOSED\_PAREN Body  
 rule.setLeft(FOR\_STMT);  
 rule.addSymbol(KEYWORD\_FOR).addSymbol(OPEN\_PAREN).addSymbol(FOR\_INIT).addSymbol(SEMICOLON)  
 .addSymbol(EXPR\_OPT).addSymbol(SEMICOLON).addSymbol(FOR\_UPDATE).addSymbol(CLOSED\_PAREN).addSymbol(BODY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 50: ForInit -> ??  
 rule.setLeft(FOR\_INIT);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 51: ForInit -> VarDeclExpr  
 rule.setLeft(FOR\_INIT);  
 rule.addSymbol(VAR\_DECL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 52: ForInit -> AssignExpr  
 rule.setLeft(FOR\_INIT);  
 rule.addSymbol(ASSIGN\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 53: ExprOpt -> ??  
 rule.setLeft(EXPR\_OPT);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 54: ExprOpt -> Expr  
 rule.setLeft(EXPR\_OPT);  
 rule.addSymbol(EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 55: ForUpdate -> ??  
 rule.setLeft(FOR\_UPDATE);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 56: ForUpdate -> AssignExpr  
 rule.setLeft(FOR\_UPDATE);  
 rule.addSymbol(ASSIGN\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 57: ForUpdate -> IncrementExpr  
 rule.setLeft(FOR\_UPDATE);  
 rule.addSymbol(INCREMENT\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 58: Body -> OPEN\_CURLY StmtList CLOSED\_CURLY  
 rule.setLeft(BODY);  
 rule.addSymbol(OPEN\_CURLY).addSymbol(STMT\_LIST).addSymbol(CLOSED\_CURLY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 59: Body -> SimpleStmt SEMICOLON  
 rule.setLeft(BODY);  
 rule.addSymbol(SIMPLE\_STMT).addSymbol(SEMICOLON);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 60: Body -> IfStmt  
 rule.setLeft(BODY);  
 rule.addSymbol(IF\_STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 61: Body -> WhileStmt  
 rule.setLeft(BODY);  
 rule.addSymbol(WHILE\_STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 62: Body -> ForStmt  
 rule.setLeft(BODY);  
 rule.addSymbol(FOR\_STMT);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 63: ExprList -> ??  
 rule.setLeft(EXPR\_LIST);  
 rule.addSymbol(); // empty  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 64: ExprList -> ExprListNonEmpty  
 rule.setLeft(EXPR\_LIST);  
 rule.addSymbol(EXPR\_LIST\_NON\_EMPTY);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 65: ExprListNonEmpty -> Expr  
 rule.setLeft(EXPR\_LIST\_NON\_EMPTY);  
 rule.addSymbol(EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 66: ExprListNonEmpty -> ExprListNonEmpty COMMA Expr  
 rule.setLeft(EXPR\_LIST\_NON\_EMPTY);  
 rule.addSymbol(EXPR\_LIST\_NON\_EMPTY).addSymbol(COMMA).addSymbol(EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 67: Expr -> LogicalExpr  
 rule.setLeft(EXPR);  
 rule.addSymbol(LOGICAL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 68: Expr -> AddressExpr  
 rule.setLeft(EXPR);  
 rule.addSymbol(ADDRESS\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 69: LogicalExpr -> RelationalExpr  
 rule.setLeft(LOGICAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 70: LogicalExpr -> LogicalExpr PIPE\_PIPE RelationalExpr  
 rule.setLeft(LOGICAL\_EXPR);  
 rule.addSymbol(LOGICAL\_EXPR).addSymbol(PIPE\_PIPE).addSymbol(RELATIONAL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 71: LogicalExpr -> LogicalExpr AMPERSAND\_AMPERSAND RelationalExpr  
 rule.setLeft(LOGICAL\_EXPR);  
 rule.addSymbol(LOGICAL\_EXPR).addSymbol(AMPERSAND\_AMPERSAND).addSymbol(RELATIONAL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 72: RelationalExpr -> AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 73: RelationalExpr -> RelationalExpr EQUALS\_EQUALS AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR).addSymbol(EQUALS\_EQUALS).addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 74: RelationalExpr -> RelationalExpr BANG\_EQUALS AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR).addSymbol(BANG\_EQUALS).addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 75: RelationalExpr -> RelationalExpr LESS\_THAN AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR).addSymbol(LESS\_THAN).addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 76: RelationalExpr -> RelationalExpr GREATER\_THAN AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR).addSymbol(GREATER\_THAN).addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 77: RelationalExpr -> RelationalExpr LESS\_THAN\_EQUALS AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR).addSymbol(LESS\_THAN\_EQUALS).addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 78: RelationalExpr -> RelationalExpr GREATER\_THAN\_EQUALS AddExpr  
 rule.setLeft(RELATIONAL\_EXPR);  
 rule.addSymbol(RELATIONAL\_EXPR).addSymbol(GREATER\_THAN\_EQUALS).addSymbol(ADD\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 79: AddExpr -> MulExpr  
 rule.setLeft(ADD\_EXPR);  
 rule.addSymbol(MUL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 80: AddExpr -> AddExpr PLUS MulExpr  
 rule.setLeft(ADD\_EXPR);  
 rule.addSymbol(ADD\_EXPR).addSymbol(PLUS).addSymbol(MUL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 81: AddExpr -> AddExpr MINUS MulExpr  
 rule.setLeft(ADD\_EXPR);  
 rule.addSymbol(ADD\_EXPR).addSymbol(MINUS).addSymbol(MUL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 82: AddExpr -> AddExpr PIPE MulExpr  
 rule.setLeft(ADD\_EXPR);  
 rule.addSymbol(ADD\_EXPR).addSymbol(PIPE).addSymbol(MUL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 83: AddExpr -> AddExpr CARET MulExpr  
 rule.setLeft(ADD\_EXPR);  
 rule.addSymbol(ADD\_EXPR).addSymbol(CARET).addSymbol(MUL\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 84: MulExpr -> UnaryExpr  
 rule.setLeft(MUL\_EXPR);  
 rule.addSymbol(UNARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 85: MulExpr -> MulExpr STAR UnaryExpr  
 rule.setLeft(MUL\_EXPR);  
 rule.addSymbol(MUL\_EXPR).addSymbol(STAR).addSymbol(UNARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 86: MulExpr -> MulExpr SLASH UnaryExpr  
 rule.setLeft(MUL\_EXPR);  
 rule.addSymbol(MUL\_EXPR).addSymbol(SLASH).addSymbol(UNARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 87: MulExpr -> MulExpr AMPERSAND UnaryExpr  
 rule.setLeft(MUL\_EXPR);  
 rule.addSymbol(MUL\_EXPR).addSymbol(AMPERSAND).addSymbol(UNARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 88: UnaryExpr -> PrimaryExpr  
 rule.setLeft(UNARY\_EXPR);  
 rule.addSymbol(PRIMARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 89: UnaryExpr -> MINUS UnaryExpr  
 rule.setLeft(UNARY\_EXPR);  
 rule.addSymbol(MINUS).addSymbol(UNARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 90: UnaryExpr -> BANG UnaryExpr  
 rule.setLeft(UNARY\_EXPR);  
 rule.addSymbol(BANG).addSymbol(UNARY\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 91: IncrementExpr -> IDENTIFIER PLUS\_PLUS  
 rule.setLeft(INCREMENT\_EXPR);  
 rule.addSymbol(IDENTIFIER).addSymbol(PLUS\_PLUS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 92: IncrementExpr -> IDENTIFIER MINUS\_MINUS  
 rule.setLeft(INCREMENT\_EXPR);  
 rule.addSymbol(IDENTIFIER).addSymbol(MINUS\_MINUS);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 93: IncrementExpr -> PLUS\_PLUS IDENTIFIER  
 rule.setLeft(INCREMENT\_EXPR);  
 rule.addSymbol(PLUS\_PLUS).addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 94: IncrementExpr -> MINUS\_MINUS IDENTIFIER  
 rule.setLeft(INCREMENT\_EXPR);  
 rule.addSymbol(MINUS\_MINUS).addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 95: AddressExpr -> AMPERSAND IDENTIFIER  
 rule.setLeft(ADDRESS\_EXPR);  
 rule.addSymbol(AMPERSAND).addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 96: DereferenceExpr -> STAR IDENTIFIER  
 rule.setLeft(DEREFERENCE\_EXPR);  
 rule.addSymbol(STAR).addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 97: PrimaryExpr -> IDENTIFIER  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(IDENTIFIER);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 98: PrimaryExpr -> IDENTIFIER OPEN\_BRACKET Expr CLOSED\_BRACKET  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(IDENTIFIER).addSymbol(OPEN\_BRACKET).addSymbol(EXPR).addSymbol(CLOSED\_BRACKET);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 99: PrimaryExpr -> INTEGER\_LITERAL  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(INTEGER\_LITERAL);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 100: PrimaryExpr -> FLOAT\_LITERAL  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(FLOAT\_LITERAL);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 101: PrimaryExpr -> CHAR\_LITERAL  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(CHAR\_LITERAL);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 102: PrimaryExpr -> OPEN\_PAREN Expr CLOSED\_PAREN  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(OPEN\_PAREN).addSymbol(EXPR).addSymbol(CLOSED\_PAREN);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 103: PrimaryExpr -> IDENTIFIER OPEN\_PAREN ExprList CLOSED\_PAREN  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(IDENTIFIER).addSymbol(OPEN\_PAREN).addSymbol(EXPR\_LIST).addSymbol(CLOSED\_PAREN);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 104: PrimaryExpr -> DereferenceExpr  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(DEREFERENCE\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
   
 // Rule 105: PrimaryExpr -> IncrementExpr  
 rule.setLeft(PRIMARY\_EXPR);  
 rule.addSymbol(INCREMENT\_EXPR);  
 addProductionRule(rule);  
 rule.reset();  
 }  
   
   
 void Parser::fillTables() {  
 // State 0  
 \_actionTable.addDefault(0, {REDUCE, 1});  
 \_gotoTable.add(0, PROGRAM, 1);  
   
 // State 1  
 \_actionTable.add(1, END\_OF\_FILE, {SHIFT, 2});  
 \_actionTable.add(1, KEYWORD\_FN, {SHIFT, 3});  
 \_gotoTable.add(1, FUNCTION\_DECL, 4);  
   
 // State 2  
 \_actionTable.addDefault(2, {ACCEPT, 0});  
   
 // State 3  
 \_actionTable.add(3, IDENTIFIER, {SHIFT, 5});  
   
 // State 4  
 \_actionTable.addDefault(4, {REDUCE, 2});  
   
 // State 5  
 \_actionTable.add(5, OPEN\_PAREN, {SHIFT, 6});  
   
 // State 6  
 \_actionTable.add(6, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(6, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(6, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.addDefault(6, {REDUCE, 4});  
 \_gotoTable.add(6, PARAM\_LIST, 10);  
 \_gotoTable.add(6, PARAM\_LIST\_NON\_EMPTY, 11);  
 \_gotoTable.add(6, PARAM, 12);  
 \_gotoTable.add(6, TYPE, 13);  
 \_gotoTable.add(6, BASE\_TYPE, 14);  
   
 // State 7  
 \_actionTable.addDefault(7, {REDUCE, 12});  
   
 // State 8  
 \_actionTable.addDefault(8, {REDUCE, 13});  
   
 // State 9  
 \_actionTable.addDefault(9, {REDUCE, 14});  
   
 // State 10  
 \_actionTable.add(10, CLOSED\_PAREN, {SHIFT, 15});  
   
 // State 11  
 \_actionTable.add(11, COMMA, {SHIFT, 16});  
 \_actionTable.addDefault(11, {REDUCE, 5});  
   
 // State 12  
 \_actionTable.addDefault(12, {REDUCE, 6});  
   
 // State 13  
 \_actionTable.add(13, IDENTIFIER, {SHIFT, 17});  
   
 // State 14  
 \_actionTable.add(14, OPEN\_BRACKET, {SHIFT, 18});  
 \_actionTable.add(14, STAR, {SHIFT, 19});  
 \_actionTable.addDefault(14, {REDUCE, 9});  
   
 // State 15  
 \_actionTable.add(15, RIGHT\_ARROW, {SHIFT, 20});  
   
 // State 16  
 \_actionTable.add(16, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(16, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(16, KEYWORD\_CHAR, {SHIFT, 9});  
 \_gotoTable.add(16, PARAM, 21);  
 \_gotoTable.add(16, TYPE, 13);  
 \_gotoTable.add(16, BASE\_TYPE, 14);  
   
 // State 17  
 \_actionTable.addDefault(17, {REDUCE, 8});  
   
 // State 18  
 \_actionTable.add(18, INTEGER\_LITERAL, {SHIFT, 22});  
   
 // State 19  
 \_actionTable.addDefault(19, {REDUCE, 11});  
   
 // State 20  
 \_actionTable.add(20, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(20, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(20, KEYWORD\_CHAR, {SHIFT, 9});  
 \_gotoTable.add(20, TYPE, 23);  
 \_gotoTable.add(20, BASE\_TYPE, 14);  
   
 // State 21  
 \_actionTable.addDefault(21, {REDUCE, 7});  
   
 // State 22  
 \_actionTable.add(22, CLOSED\_BRACKET, {SHIFT, 24});  
   
 // State 23  
 \_actionTable.add(23, OPEN\_CURLY, {SHIFT, 25});  
   
 // State 24  
 \_actionTable.addDefault(24, {REDUCE, 10});  
   
 // State 25  
 \_actionTable.addDefault(25, {REDUCE, 15});  
 \_gotoTable.add(25, STMT\_LIST, 26);  
   
 // State 26  
 \_actionTable.add(26, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(26, OPEN\_CURLY, {SHIFT, 28});  
 \_actionTable.add(26, CLOSED\_CURLY, {SHIFT, 29});  
 \_actionTable.add(26, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(26, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(26, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(26, STAR, {SHIFT, 30});  
 \_actionTable.add(26, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(26, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(26, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(26, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(26, TYPE, 35);  
 \_gotoTable.add(26, BASE\_TYPE, 14);  
 \_gotoTable.add(26, STMT, 36);  
 \_gotoTable.add(26, SIMPLE\_STMT, 37);  
 \_gotoTable.add(26, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(26, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(26, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(26, IF\_STMT, 41);  
 \_gotoTable.add(26, WHILE\_STMT, 42);  
 \_gotoTable.add(26, FOR\_STMT, 43);  
   
 // State 27  
 \_actionTable.add(27, OPEN\_PAREN, {SHIFT, 44});  
 \_actionTable.add(27, OPEN\_BRACKET, {SHIFT, 45});  
 \_actionTable.addDefault(27, {REDUCE, 32});  
   
 // State 28  
 \_actionTable.addDefault(28, {REDUCE, 15});  
 \_gotoTable.add(28, STMT\_LIST, 46);  
   
 // State 29  
 \_actionTable.addDefault(29, {REDUCE, 3});  
   
 // State 30  
 \_actionTable.add(30, IDENTIFIER, {SHIFT, 47});  
   
 // State 31  
 \_actionTable.add(31, OPEN\_PAREN, {SHIFT, 48});  
   
 // State 32  
 \_actionTable.add(32, OPEN\_PAREN, {SHIFT, 49});  
   
 // State 33  
 \_actionTable.add(33, OPEN\_PAREN, {SHIFT, 50});  
   
 // State 34  
 \_actionTable.add(34, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(34, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(34, STAR, {SHIFT, 53});  
 \_actionTable.add(34, MINUS, {SHIFT, 54});  
 \_actionTable.add(34, BANG, {SHIFT, 55});  
 \_actionTable.add(34, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(34, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(34, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(34, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(34, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(34, MINUS\_MINUS, {SHIFT, 61});  
 \_actionTable.addDefault(34, {REDUCE, 53});  
 \_gotoTable.add(34, EXPR\_OPT, 62);  
 \_gotoTable.add(34, EXPR, 63);  
 \_gotoTable.add(34, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(34, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(34, ADD\_EXPR, 66);  
 \_gotoTable.add(34, MUL\_EXPR, 67);  
 \_gotoTable.add(34, UNARY\_EXPR, 68);  
 \_gotoTable.add(34, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(34, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(34, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(34, PRIMARY\_EXPR, 72);  
   
 // State 35  
 \_actionTable.add(35, IDENTIFIER, {SHIFT, 73});  
   
 // State 36  
 \_actionTable.addDefault(36, {REDUCE, 16});  
   
 // State 37  
 \_actionTable.add(37, SEMICOLON, {SHIFT, 74});  
   
 // State 38  
 \_actionTable.addDefault(38, {REDUCE, 22});  
   
 // State 39  
 \_actionTable.addDefault(39, {REDUCE, 23});  
   
 // State 40  
 \_actionTable.add(40, EQUALS, {SHIFT, 75});  
 \_actionTable.add(40, PLUS\_EQUALS, {SHIFT, 76});  
 \_actionTable.add(40, MINUS\_EQUALS, {SHIFT, 77});  
 \_actionTable.add(40, SLASH\_EQUALS, {SHIFT, 78});  
 \_actionTable.add(40, STAR\_EQUALS, {SHIFT, 79});  
 \_actionTable.add(40, AMPERSAND\_EQUALS, {SHIFT, 80});  
 \_actionTable.add(40, PIPE\_EQUALS, {SHIFT, 81});  
 \_actionTable.add(40, CARET\_EQUALS, {SHIFT, 82});  
 \_actionTable.add(40, TILDE\_EQUALS, {SHIFT, 83});  
 \_gotoTable.add(40, ASSIGN\_OP, 84);  
   
 // State 41  
 \_actionTable.addDefault(41, {REDUCE, 19});  
   
 // State 42  
 \_actionTable.addDefault(42, {REDUCE, 20});  
   
 // State 43  
 \_actionTable.addDefault(43, {REDUCE, 21});  
   
 // State 44  
 \_actionTable.add(44, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(44, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(44, STAR, {SHIFT, 53});  
 \_actionTable.add(44, MINUS, {SHIFT, 54});  
 \_actionTable.add(44, BANG, {SHIFT, 55});  
 \_actionTable.add(44, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(44, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(44, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(44, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(44, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(44, MINUS\_MINUS, {SHIFT, 61});  
 \_actionTable.addDefault(44, {REDUCE, 63});  
 \_gotoTable.add(44, EXPR\_LIST, 85);  
 \_gotoTable.add(44, EXPR\_LIST\_NON\_EMPTY, 86);  
 \_gotoTable.add(44, EXPR, 87);  
 \_gotoTable.add(44, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(44, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(44, ADD\_EXPR, 66);  
 \_gotoTable.add(44, MUL\_EXPR, 67);  
 \_gotoTable.add(44, UNARY\_EXPR, 68);  
 \_gotoTable.add(44, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(44, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(44, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(44, PRIMARY\_EXPR, 72);  
   
 // State 45  
 \_actionTable.add(45, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(45, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(45, STAR, {SHIFT, 53});  
 \_actionTable.add(45, MINUS, {SHIFT, 54});  
 \_actionTable.add(45, BANG, {SHIFT, 55});  
 \_actionTable.add(45, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(45, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(45, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(45, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(45, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(45, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(45, EXPR, 88);  
 \_gotoTable.add(45, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(45, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(45, ADD\_EXPR, 66);  
 \_gotoTable.add(45, MUL\_EXPR, 67);  
 \_gotoTable.add(45, UNARY\_EXPR, 68);  
 \_gotoTable.add(45, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(45, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(45, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(45, PRIMARY\_EXPR, 72);  
   
 // State 46  
 \_actionTable.add(46, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(46, OPEN\_CURLY, {SHIFT, 28});  
 \_actionTable.add(46, CLOSED\_CURLY, {SHIFT, 89});  
 \_actionTable.add(46, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(46, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(46, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(46, STAR, {SHIFT, 30});  
 \_actionTable.add(46, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(46, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(46, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(46, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(46, TYPE, 35);  
 \_gotoTable.add(46, BASE\_TYPE, 14);  
 \_gotoTable.add(46, STMT, 36);  
 \_gotoTable.add(46, SIMPLE\_STMT, 37);  
 \_gotoTable.add(46, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(46, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(46, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(46, IF\_STMT, 41);  
 \_gotoTable.add(46, WHILE\_STMT, 42);  
 \_gotoTable.add(46, FOR\_STMT, 43);  
   
 // State 47  
 \_actionTable.addDefault(47, {REDUCE, 34});  
   
 // State 48  
 \_actionTable.add(48, IDENTIFIER, {SHIFT, 90});  
 \_actionTable.add(48, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(48, STAR, {SHIFT, 91});  
 \_actionTable.add(48, MINUS, {SHIFT, 54});  
 \_actionTable.add(48, BANG, {SHIFT, 55});  
 \_actionTable.add(48, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(48, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(48, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(48, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(48, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(48, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(48, ASSIGN\_EXPR, 92);  
 \_gotoTable.add(48, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(48, CONDITION\_OP, 93);  
 \_gotoTable.add(48, EXPR, 94);  
 \_gotoTable.add(48, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(48, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(48, ADD\_EXPR, 66);  
 \_gotoTable.add(48, MUL\_EXPR, 67);  
 \_gotoTable.add(48, UNARY\_EXPR, 68);  
 \_gotoTable.add(48, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(48, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(48, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(48, PRIMARY\_EXPR, 72);  
   
 // State 49  
 \_actionTable.add(49, IDENTIFIER, {SHIFT, 90});  
 \_actionTable.add(49, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(49, STAR, {SHIFT, 91});  
 \_actionTable.add(49, MINUS, {SHIFT, 54});  
 \_actionTable.add(49, BANG, {SHIFT, 55});  
 \_actionTable.add(49, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(49, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(49, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(49, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(49, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(49, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(49, ASSIGN\_EXPR, 92);  
 \_gotoTable.add(49, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(49, CONDITION\_OP, 95);  
 \_gotoTable.add(49, EXPR, 94);  
 \_gotoTable.add(49, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(49, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(49, ADD\_EXPR, 66);  
 \_gotoTable.add(49, MUL\_EXPR, 67);  
 \_gotoTable.add(49, UNARY\_EXPR, 68);  
 \_gotoTable.add(49, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(49, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(49, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(49, PRIMARY\_EXPR, 72);  
   
 // State 50  
 \_actionTable.add(50, IDENTIFIER, {SHIFT, 96});  
 \_actionTable.add(50, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(50, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(50, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(50, STAR, {SHIFT, 30});  
 \_actionTable.addDefault(50, {REDUCE, 50});  
 \_gotoTable.add(50, TYPE, 35);  
 \_gotoTable.add(50, BASE\_TYPE, 14);  
 \_gotoTable.add(50, VAR\_DECL\_EXPR, 97);  
 \_gotoTable.add(50, ASSIGN\_EXPR, 98);  
 \_gotoTable.add(50, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(50, FOR\_INIT, 99);  
   
 // State 51  
 \_actionTable.add(51, OPEN\_PAREN, {SHIFT, 100});  
 \_actionTable.add(51, OPEN\_BRACKET, {SHIFT, 101});  
 \_actionTable.add(51, PLUS\_PLUS, {SHIFT, 102});  
 \_actionTable.add(51, MINUS\_MINUS, {SHIFT, 103});  
 \_actionTable.addDefault(51, {REDUCE, 97});  
   
 // State 52  
 \_actionTable.add(52, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(52, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(52, STAR, {SHIFT, 53});  
 \_actionTable.add(52, MINUS, {SHIFT, 54});  
 \_actionTable.add(52, BANG, {SHIFT, 55});  
 \_actionTable.add(52, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(52, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(52, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(52, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(52, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(52, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(52, EXPR, 104);  
 \_gotoTable.add(52, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(52, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(52, ADD\_EXPR, 66);  
 \_gotoTable.add(52, MUL\_EXPR, 67);  
 \_gotoTable.add(52, UNARY\_EXPR, 68);  
 \_gotoTable.add(52, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(52, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(52, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(52, PRIMARY\_EXPR, 72);  
   
 // State 53  
 \_actionTable.add(53, IDENTIFIER, {SHIFT, 105});  
   
 // State 54  
 \_actionTable.add(54, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(54, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(54, STAR, {SHIFT, 53});  
 \_actionTable.add(54, MINUS, {SHIFT, 54});  
 \_actionTable.add(54, BANG, {SHIFT, 55});  
 \_actionTable.add(54, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(54, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(54, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(54, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(54, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(54, UNARY\_EXPR, 106);  
 \_gotoTable.add(54, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(54, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(54, PRIMARY\_EXPR, 72);  
   
 // State 55  
 \_actionTable.add(55, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(55, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(55, STAR, {SHIFT, 53});  
 \_actionTable.add(55, MINUS, {SHIFT, 54});  
 \_actionTable.add(55, BANG, {SHIFT, 55});  
 \_actionTable.add(55, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(55, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(55, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(55, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(55, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(55, UNARY\_EXPR, 107);  
 \_gotoTable.add(55, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(55, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(55, PRIMARY\_EXPR, 72);  
   
 // State 56  
 \_actionTable.add(56, IDENTIFIER, {SHIFT, 108});  
   
 // State 57  
 \_actionTable.addDefault(57, {REDUCE, 99});  
   
 // State 58  
 \_actionTable.addDefault(58, {REDUCE, 100});  
   
 // State 59  
 \_actionTable.addDefault(59, {REDUCE, 101});  
   
 // State 60  
 \_actionTable.add(60, IDENTIFIER, {SHIFT, 109});  
   
 // State 61  
 \_actionTable.add(61, IDENTIFIER, {SHIFT, 110});  
   
 // State 62  
 \_actionTable.addDefault(62, {REDUCE, 25});  
   
 // State 63  
 \_actionTable.addDefault(63, {REDUCE, 54});  
   
 // State 64  
 \_actionTable.add(64, PIPE\_PIPE, {SHIFT, 111});  
 \_actionTable.add(64, AMPERSAND\_AMPERSAND, {SHIFT, 112});  
 \_actionTable.addDefault(64, {REDUCE, 67});  
   
 // State 65  
 \_actionTable.add(65, LESS\_THAN, {SHIFT, 113});  
 \_actionTable.add(65, GREATER\_THAN, {SHIFT, 114});  
 \_actionTable.add(65, LESS\_THAN\_EQUALS, {SHIFT, 115});  
 \_actionTable.add(65, GREATER\_THAN\_EQUALS, {SHIFT, 116});  
 \_actionTable.add(65, EQUALS\_EQUALS, {SHIFT, 117});  
 \_actionTable.add(65, BANG\_EQUALS, {SHIFT, 118});  
 \_actionTable.addDefault(65, {REDUCE, 69});  
   
 // State 66  
 \_actionTable.add(66, MINUS, {SHIFT, 119});  
 \_actionTable.add(66, PLUS, {SHIFT, 120});  
 \_actionTable.add(66, PIPE, {SHIFT, 121});  
 \_actionTable.add(66, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(66, {REDUCE, 72});  
   
 // State 67  
 \_actionTable.add(67, STAR, {SHIFT, 123});  
 \_actionTable.add(67, SLASH, {SHIFT, 124});  
 \_actionTable.add(67, AMPERSAND, {SHIFT, 125});  
 \_actionTable.addDefault(67, {REDUCE, 79});  
   
 // State 68  
 \_actionTable.addDefault(68, {REDUCE, 84});  
   
 // State 69  
 \_actionTable.addDefault(69, {REDUCE, 105});  
   
 // State 70  
 \_actionTable.addDefault(70, {REDUCE, 68});  
   
 // State 71  
 \_actionTable.addDefault(71, {REDUCE, 104});  
   
 // State 72  
 \_actionTable.addDefault(72, {REDUCE, 88});  
   
 // State 73  
 \_actionTable.add(73, EQUALS, {SHIFT, 126});  
 \_actionTable.addDefault(73, {REDUCE, 27});  
 \_gotoTable.add(73, INIT\_OPT, 127);  
   
 // State 74  
 \_actionTable.addDefault(74, {REDUCE, 17});  
   
 // State 75  
 \_actionTable.addDefault(75, {REDUCE, 35});  
   
 // State 76  
 \_actionTable.addDefault(76, {REDUCE, 36});  
   
 // State 77  
 \_actionTable.addDefault(77, {REDUCE, 37});  
   
 // State 78  
 \_actionTable.addDefault(78, {REDUCE, 38});  
   
 // State 79  
 \_actionTable.addDefault(79, {REDUCE, 39});  
   
 // State 80  
 \_actionTable.addDefault(80, {REDUCE, 40});  
   
 // State 81  
 \_actionTable.addDefault(81, {REDUCE, 41});  
   
 // State 82  
 \_actionTable.addDefault(82, {REDUCE, 42});  
   
 // State 83  
 \_actionTable.addDefault(83, {REDUCE, 43});  
   
 // State 84  
 \_actionTable.add(84, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(84, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(84, STAR, {SHIFT, 53});  
 \_actionTable.add(84, MINUS, {SHIFT, 54});  
 \_actionTable.add(84, BANG, {SHIFT, 55});  
 \_actionTable.add(84, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(84, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(84, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(84, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(84, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(84, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(84, EXPR, 128);  
 \_gotoTable.add(84, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(84, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(84, ADD\_EXPR, 66);  
 \_gotoTable.add(84, MUL\_EXPR, 67);  
 \_gotoTable.add(84, UNARY\_EXPR, 68);  
 \_gotoTable.add(84, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(84, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(84, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(84, PRIMARY\_EXPR, 72);  
   
 // State 85  
 \_actionTable.add(85, CLOSED\_PAREN, {SHIFT, 129});  
   
 // State 86  
 \_actionTable.add(86, COMMA, {SHIFT, 130});  
 \_actionTable.addDefault(86, {REDUCE, 64});  
   
 // State 87  
 \_actionTable.addDefault(87, {REDUCE, 65});  
   
 // State 88  
 \_actionTable.add(88, CLOSED\_BRACKET, {SHIFT, 131});  
   
 // State 89  
 \_actionTable.addDefault(89, {REDUCE, 18});  
   
 // State 90  
 \_actionTable.add(90, OPEN\_PAREN, {SHIFT, 100});  
 \_actionTable.add(90, OPEN\_BRACKET, {SHIFT, 132});  
 \_actionTable.add(90, PLUS\_PLUS, {SHIFT, 102});  
 \_actionTable.add(90, MINUS\_MINUS, {SHIFT, 103});  
 \_actionTable.add(90, EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, PLUS\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, MINUS\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, SLASH\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, STAR\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, AMPERSAND\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, PIPE\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, CARET\_EQUALS, {REDUCE, 32});  
 \_actionTable.add(90, TILDE\_EQUALS, {REDUCE, 32});  
 \_actionTable.addDefault(90, {REDUCE, 97});  
   
 // State 91  
 \_actionTable.add(91, IDENTIFIER, {SHIFT, 133});  
   
 // State 92  
 \_actionTable.addDefault(92, {REDUCE, 48});  
   
 // State 93  
 \_actionTable.add(93, CLOSED\_PAREN, {SHIFT, 134});  
   
 // State 94  
 \_actionTable.addDefault(94, {REDUCE, 47});  
   
 // State 95  
 \_actionTable.add(95, CLOSED\_PAREN, {SHIFT, 135});  
   
 // State 96  
 \_actionTable.add(96, OPEN\_BRACKET, {SHIFT, 45});  
 \_actionTable.addDefault(96, {REDUCE, 32});  
   
 // State 97  
 \_actionTable.addDefault(97, {REDUCE, 51});  
   
 // State 98  
 \_actionTable.addDefault(98, {REDUCE, 52});  
   
 // State 99  
 \_actionTable.add(99, SEMICOLON, {SHIFT, 136});  
   
 // State 100  
 \_actionTable.add(100, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(100, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(100, STAR, {SHIFT, 53});  
 \_actionTable.add(100, MINUS, {SHIFT, 54});  
 \_actionTable.add(100, BANG, {SHIFT, 55});  
 \_actionTable.add(100, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(100, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(100, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(100, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(100, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(100, MINUS\_MINUS, {SHIFT, 61});  
 \_actionTable.addDefault(100, {REDUCE, 63});  
 \_gotoTable.add(100, EXPR\_LIST, 137);  
 \_gotoTable.add(100, EXPR\_LIST\_NON\_EMPTY, 86);  
 \_gotoTable.add(100, EXPR, 87);  
 \_gotoTable.add(100, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(100, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(100, ADD\_EXPR, 66);  
 \_gotoTable.add(100, MUL\_EXPR, 67);  
 \_gotoTable.add(100, UNARY\_EXPR, 68);  
 \_gotoTable.add(100, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(100, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(100, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(100, PRIMARY\_EXPR, 72);  
   
 // State 101  
 \_actionTable.add(101, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(101, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(101, STAR, {SHIFT, 53});  
 \_actionTable.add(101, MINUS, {SHIFT, 54});  
 \_actionTable.add(101, BANG, {SHIFT, 55});  
 \_actionTable.add(101, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(101, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(101, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(101, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(101, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(101, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(101, EXPR, 138);  
 \_gotoTable.add(101, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(101, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(101, ADD\_EXPR, 66);  
 \_gotoTable.add(101, MUL\_EXPR, 67);  
 \_gotoTable.add(101, UNARY\_EXPR, 68);  
 \_gotoTable.add(101, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(101, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(101, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(101, PRIMARY\_EXPR, 72);  
   
 // State 102  
 \_actionTable.addDefault(102, {REDUCE, 91});  
   
 // State 103  
 \_actionTable.addDefault(103, {REDUCE, 92});  
   
 // State 104  
 \_actionTable.add(104, CLOSED\_PAREN, {SHIFT, 139});  
   
 // State 105  
 \_actionTable.addDefault(105, {REDUCE, 96});  
   
 // State 106  
 \_actionTable.addDefault(106, {REDUCE, 89});  
   
 // State 107  
 \_actionTable.addDefault(107, {REDUCE, 90});  
   
 // State 108  
 \_actionTable.addDefault(108, {REDUCE, 95});  
   
 // State 109  
 \_actionTable.addDefault(109, {REDUCE, 93});  
   
 // State 110  
 \_actionTable.addDefault(110, {REDUCE, 94});  
   
 // State 111  
 \_actionTable.add(111, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(111, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(111, STAR, {SHIFT, 53});  
 \_actionTable.add(111, MINUS, {SHIFT, 54});  
 \_actionTable.add(111, BANG, {SHIFT, 55});  
 \_actionTable.add(111, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(111, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(111, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(111, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(111, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(111, RELATIONAL\_EXPR, 140);  
 \_gotoTable.add(111, ADD\_EXPR, 66);  
 \_gotoTable.add(111, MUL\_EXPR, 67);  
 \_gotoTable.add(111, UNARY\_EXPR, 68);  
 \_gotoTable.add(111, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(111, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(111, PRIMARY\_EXPR, 72);  
   
 // State 112  
 \_actionTable.add(112, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(112, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(112, STAR, {SHIFT, 53});  
 \_actionTable.add(112, MINUS, {SHIFT, 54});  
 \_actionTable.add(112, BANG, {SHIFT, 55});  
 \_actionTable.add(112, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(112, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(112, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(112, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(112, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(112, RELATIONAL\_EXPR, 141);  
 \_gotoTable.add(112, ADD\_EXPR, 66);  
 \_gotoTable.add(112, MUL\_EXPR, 67);  
 \_gotoTable.add(112, UNARY\_EXPR, 68);  
 \_gotoTable.add(112, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(112, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(112, PRIMARY\_EXPR, 72);  
   
 // State 113  
 \_actionTable.add(113, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(113, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(113, STAR, {SHIFT, 53});  
 \_actionTable.add(113, MINUS, {SHIFT, 54});  
 \_actionTable.add(113, BANG, {SHIFT, 55});  
 \_actionTable.add(113, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(113, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(113, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(113, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(113, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(113, ADD\_EXPR, 142);  
 \_gotoTable.add(113, MUL\_EXPR, 67);  
 \_gotoTable.add(113, UNARY\_EXPR, 68);  
 \_gotoTable.add(113, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(113, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(113, PRIMARY\_EXPR, 72);  
   
 // State 114  
 \_actionTable.add(114, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(114, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(114, STAR, {SHIFT, 53});  
 \_actionTable.add(114, MINUS, {SHIFT, 54});  
 \_actionTable.add(114, BANG, {SHIFT, 55});  
 \_actionTable.add(114, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(114, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(114, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(114, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(114, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(114, ADD\_EXPR, 143);  
 \_gotoTable.add(114, MUL\_EXPR, 67);  
 \_gotoTable.add(114, UNARY\_EXPR, 68);  
 \_gotoTable.add(114, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(114, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(114, PRIMARY\_EXPR, 72);  
   
 // State 115  
 \_actionTable.add(115, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(115, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(115, STAR, {SHIFT, 53});  
 \_actionTable.add(115, MINUS, {SHIFT, 54});  
 \_actionTable.add(115, BANG, {SHIFT, 55});  
 \_actionTable.add(115, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(115, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(115, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(115, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(115, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(115, ADD\_EXPR, 144);  
 \_gotoTable.add(115, MUL\_EXPR, 67);  
 \_gotoTable.add(115, UNARY\_EXPR, 68);  
 \_gotoTable.add(115, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(115, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(115, PRIMARY\_EXPR, 72);  
   
 // State 116  
 \_actionTable.add(116, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(116, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(116, STAR, {SHIFT, 53});  
 \_actionTable.add(116, MINUS, {SHIFT, 54});  
 \_actionTable.add(116, BANG, {SHIFT, 55});  
 \_actionTable.add(116, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(116, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(116, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(116, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(116, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(116, ADD\_EXPR, 145);  
 \_gotoTable.add(116, MUL\_EXPR, 67);  
 \_gotoTable.add(116, UNARY\_EXPR, 68);  
 \_gotoTable.add(116, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(116, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(116, PRIMARY\_EXPR, 72);  
   
 // State 117  
 \_actionTable.add(117, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(117, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(117, STAR, {SHIFT, 53});  
 \_actionTable.add(117, MINUS, {SHIFT, 54});  
 \_actionTable.add(117, BANG, {SHIFT, 55});  
 \_actionTable.add(117, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(117, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(117, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(117, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(117, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(117, ADD\_EXPR, 146);  
 \_gotoTable.add(117, MUL\_EXPR, 67);  
 \_gotoTable.add(117, UNARY\_EXPR, 68);  
 \_gotoTable.add(117, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(117, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(117, PRIMARY\_EXPR, 72);  
   
 // State 118  
 \_actionTable.add(118, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(118, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(118, STAR, {SHIFT, 53});  
 \_actionTable.add(118, MINUS, {SHIFT, 54});  
 \_actionTable.add(118, BANG, {SHIFT, 55});  
 \_actionTable.add(118, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(118, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(118, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(118, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(118, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(118, ADD\_EXPR, 147);  
 \_gotoTable.add(118, MUL\_EXPR, 67);  
 \_gotoTable.add(118, UNARY\_EXPR, 68);  
 \_gotoTable.add(118, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(118, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(118, PRIMARY\_EXPR, 72);  
   
 // State 119  
 \_actionTable.add(119, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(119, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(119, STAR, {SHIFT, 53});  
 \_actionTable.add(119, MINUS, {SHIFT, 54});  
 \_actionTable.add(119, BANG, {SHIFT, 55});  
 \_actionTable.add(119, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(119, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(119, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(119, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(119, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(119, MUL\_EXPR, 148);  
 \_gotoTable.add(119, UNARY\_EXPR, 68);  
 \_gotoTable.add(119, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(119, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(119, PRIMARY\_EXPR, 72);  
   
 // State 120  
 \_actionTable.add(120, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(120, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(120, STAR, {SHIFT, 53});  
 \_actionTable.add(120, MINUS, {SHIFT, 54});  
 \_actionTable.add(120, BANG, {SHIFT, 55});  
 \_actionTable.add(120, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(120, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(120, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(120, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(120, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(120, MUL\_EXPR, 149);  
 \_gotoTable.add(120, UNARY\_EXPR, 68);  
 \_gotoTable.add(120, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(120, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(120, PRIMARY\_EXPR, 72);  
   
 // State 121  
 \_actionTable.add(121, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(121, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(121, STAR, {SHIFT, 53});  
 \_actionTable.add(121, MINUS, {SHIFT, 54});  
 \_actionTable.add(121, BANG, {SHIFT, 55});  
 \_actionTable.add(121, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(121, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(121, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(121, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(121, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(121, MUL\_EXPR, 150);  
 \_gotoTable.add(121, UNARY\_EXPR, 68);  
 \_gotoTable.add(121, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(121, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(121, PRIMARY\_EXPR, 72);  
   
 // State 122  
 \_actionTable.add(122, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(122, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(122, STAR, {SHIFT, 53});  
 \_actionTable.add(122, MINUS, {SHIFT, 54});  
 \_actionTable.add(122, BANG, {SHIFT, 55});  
 \_actionTable.add(122, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(122, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(122, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(122, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(122, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(122, MUL\_EXPR, 151);  
 \_gotoTable.add(122, UNARY\_EXPR, 68);  
 \_gotoTable.add(122, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(122, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(122, PRIMARY\_EXPR, 72);  
   
 // State 123  
 \_actionTable.add(123, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(123, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(123, STAR, {SHIFT, 53});  
 \_actionTable.add(123, MINUS, {SHIFT, 54});  
 \_actionTable.add(123, BANG, {SHIFT, 55});  
 \_actionTable.add(123, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(123, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(123, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(123, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(123, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(123, UNARY\_EXPR, 152);  
 \_gotoTable.add(123, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(123, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(123, PRIMARY\_EXPR, 72);  
   
 // State 124  
 \_actionTable.add(124, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(124, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(124, STAR, {SHIFT, 53});  
 \_actionTable.add(124, MINUS, {SHIFT, 54});  
 \_actionTable.add(124, BANG, {SHIFT, 55});  
 \_actionTable.add(124, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(124, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(124, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(124, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(124, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(124, UNARY\_EXPR, 153);  
 \_gotoTable.add(124, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(124, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(124, PRIMARY\_EXPR, 72);  
   
 // State 125  
 \_actionTable.add(125, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(125, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(125, STAR, {SHIFT, 53});  
 \_actionTable.add(125, MINUS, {SHIFT, 54});  
 \_actionTable.add(125, BANG, {SHIFT, 55});  
 \_actionTable.add(125, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(125, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(125, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(125, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(125, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(125, UNARY\_EXPR, 154);  
 \_gotoTable.add(125, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(125, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(125, PRIMARY\_EXPR, 72);  
   
 // State 126  
 \_actionTable.add(126, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(126, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(126, OPEN\_CURLY, {SHIFT, 155});  
 \_actionTable.add(126, STAR, {SHIFT, 53});  
 \_actionTable.add(126, MINUS, {SHIFT, 54});  
 \_actionTable.add(126, BANG, {SHIFT, 55});  
 \_actionTable.add(126, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(126, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(126, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(126, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(126, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(126, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(126, ASSIGN\_VALUE, 156);  
 \_gotoTable.add(126, EXPR, 157);  
 \_gotoTable.add(126, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(126, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(126, ADD\_EXPR, 66);  
 \_gotoTable.add(126, MUL\_EXPR, 67);  
 \_gotoTable.add(126, UNARY\_EXPR, 68);  
 \_gotoTable.add(126, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(126, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(126, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(126, PRIMARY\_EXPR, 72);  
   
 // State 127  
 \_actionTable.addDefault(127, {REDUCE, 26});  
   
 // State 128  
 \_actionTable.addDefault(128, {REDUCE, 31});  
   
 // State 129  
 \_actionTable.addDefault(129, {REDUCE, 24});  
   
 // State 130  
 \_actionTable.add(130, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(130, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(130, STAR, {SHIFT, 53});  
 \_actionTable.add(130, MINUS, {SHIFT, 54});  
 \_actionTable.add(130, BANG, {SHIFT, 55});  
 \_actionTable.add(130, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(130, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(130, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(130, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(130, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(130, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(130, EXPR, 158);  
 \_gotoTable.add(130, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(130, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(130, ADD\_EXPR, 66);  
 \_gotoTable.add(130, MUL\_EXPR, 67);  
 \_gotoTable.add(130, UNARY\_EXPR, 68);  
 \_gotoTable.add(130, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(130, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(130, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(130, PRIMARY\_EXPR, 72);  
   
 // State 131  
 \_actionTable.addDefault(131, {REDUCE, 33});  
   
 // State 132  
 \_actionTable.add(132, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(132, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(132, STAR, {SHIFT, 53});  
 \_actionTable.add(132, MINUS, {SHIFT, 54});  
 \_actionTable.add(132, BANG, {SHIFT, 55});  
 \_actionTable.add(132, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(132, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(132, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(132, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(132, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(132, MINUS\_MINUS, {SHIFT, 61});  
 \_gotoTable.add(132, EXPR, 159);  
 \_gotoTable.add(132, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(132, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(132, ADD\_EXPR, 66);  
 \_gotoTable.add(132, MUL\_EXPR, 67);  
 \_gotoTable.add(132, UNARY\_EXPR, 68);  
 \_gotoTable.add(132, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(132, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(132, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(132, PRIMARY\_EXPR, 72);  
   
 // State 133  
 \_actionTable.add(133, EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, PLUS\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, MINUS\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, SLASH\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, STAR\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, AMPERSAND\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, PIPE\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, CARET\_EQUALS, {REDUCE, 34});  
 \_actionTable.add(133, TILDE\_EQUALS, {REDUCE, 34});  
 \_actionTable.addDefault(133, {REDUCE, 96});  
   
 // State 134  
 \_actionTable.add(134, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(134, OPEN\_CURLY, {SHIFT, 160});  
 \_actionTable.add(134, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(134, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(134, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(134, STAR, {SHIFT, 30});  
 \_actionTable.add(134, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(134, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(134, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(134, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(134, TYPE, 35);  
 \_gotoTable.add(134, BASE\_TYPE, 14);  
 \_gotoTable.add(134, SIMPLE\_STMT, 161);  
 \_gotoTable.add(134, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(134, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(134, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(134, IF\_STMT, 162);  
 \_gotoTable.add(134, WHILE\_STMT, 163);  
 \_gotoTable.add(134, FOR\_STMT, 164);  
 \_gotoTable.add(134, BODY, 165);  
   
 // State 135  
 \_actionTable.add(135, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(135, OPEN\_CURLY, {SHIFT, 160});  
 \_actionTable.add(135, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(135, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(135, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(135, STAR, {SHIFT, 30});  
 \_actionTable.add(135, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(135, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(135, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(135, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(135, TYPE, 35);  
 \_gotoTable.add(135, BASE\_TYPE, 14);  
 \_gotoTable.add(135, SIMPLE\_STMT, 161);  
 \_gotoTable.add(135, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(135, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(135, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(135, IF\_STMT, 162);  
 \_gotoTable.add(135, WHILE\_STMT, 163);  
 \_gotoTable.add(135, FOR\_STMT, 164);  
 \_gotoTable.add(135, BODY, 166);  
   
 // State 136  
 \_actionTable.add(136, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(136, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(136, STAR, {SHIFT, 53});  
 \_actionTable.add(136, MINUS, {SHIFT, 54});  
 \_actionTable.add(136, BANG, {SHIFT, 55});  
 \_actionTable.add(136, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(136, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(136, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(136, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(136, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(136, MINUS\_MINUS, {SHIFT, 61});  
 \_actionTable.addDefault(136, {REDUCE, 53});  
 \_gotoTable.add(136, EXPR\_OPT, 167);  
 \_gotoTable.add(136, EXPR, 63);  
 \_gotoTable.add(136, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(136, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(136, ADD\_EXPR, 66);  
 \_gotoTable.add(136, MUL\_EXPR, 67);  
 \_gotoTable.add(136, UNARY\_EXPR, 68);  
 \_gotoTable.add(136, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(136, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(136, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(136, PRIMARY\_EXPR, 72);  
   
 // State 137  
 \_actionTable.add(137, CLOSED\_PAREN, {SHIFT, 168});  
   
 // State 138  
 \_actionTable.add(138, CLOSED\_BRACKET, {SHIFT, 169});  
   
 // State 139  
 \_actionTable.addDefault(139, {REDUCE, 102});  
   
 // State 140  
 \_actionTable.add(140, LESS\_THAN, {SHIFT, 113});  
 \_actionTable.add(140, GREATER\_THAN, {SHIFT, 114});  
 \_actionTable.add(140, LESS\_THAN\_EQUALS, {SHIFT, 115});  
 \_actionTable.add(140, GREATER\_THAN\_EQUALS, {SHIFT, 116});  
 \_actionTable.add(140, EQUALS\_EQUALS, {SHIFT, 117});  
 \_actionTable.add(140, BANG\_EQUALS, {SHIFT, 118});  
 \_actionTable.addDefault(140, {REDUCE, 70});  
   
 // State 141  
 \_actionTable.add(141, LESS\_THAN, {SHIFT, 113});  
 \_actionTable.add(141, GREATER\_THAN, {SHIFT, 114});  
 \_actionTable.add(141, LESS\_THAN\_EQUALS, {SHIFT, 115});  
 \_actionTable.add(141, GREATER\_THAN\_EQUALS, {SHIFT, 116});  
 \_actionTable.add(141, EQUALS\_EQUALS, {SHIFT, 117});  
 \_actionTable.add(141, BANG\_EQUALS, {SHIFT, 118});  
 \_actionTable.addDefault(141, {REDUCE, 71});  
   
 // State 142  
 \_actionTable.add(142, MINUS, {SHIFT, 119});  
 \_actionTable.add(142, PLUS, {SHIFT, 120});  
 \_actionTable.add(142, PIPE, {SHIFT, 121});  
 \_actionTable.add(142, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(142, {REDUCE, 75});  
   
 // State 143  
 \_actionTable.add(143, MINUS, {SHIFT, 119});  
 \_actionTable.add(143, PLUS, {SHIFT, 120});  
 \_actionTable.add(143, PIPE, {SHIFT, 121});  
 \_actionTable.add(143, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(143, {REDUCE, 76});  
   
 // State 144  
 \_actionTable.add(144, MINUS, {SHIFT, 119});  
 \_actionTable.add(144, PLUS, {SHIFT, 120});  
 \_actionTable.add(144, PIPE, {SHIFT, 121});  
 \_actionTable.add(144, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(144, {REDUCE, 77});  
   
 // State 145  
 \_actionTable.add(145, MINUS, {SHIFT, 119});  
 \_actionTable.add(145, PLUS, {SHIFT, 120});  
 \_actionTable.add(145, PIPE, {SHIFT, 121});  
 \_actionTable.add(145, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(145, {REDUCE, 78});  
   
 // State 146  
 \_actionTable.add(146, MINUS, {SHIFT, 119});  
 \_actionTable.add(146, PLUS, {SHIFT, 120});  
 \_actionTable.add(146, PIPE, {SHIFT, 121});  
 \_actionTable.add(146, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(146, {REDUCE, 73});  
   
 // State 147  
 \_actionTable.add(147, MINUS, {SHIFT, 119});  
 \_actionTable.add(147, PLUS, {SHIFT, 120});  
 \_actionTable.add(147, PIPE, {SHIFT, 121});  
 \_actionTable.add(147, CARET, {SHIFT, 122});  
 \_actionTable.addDefault(147, {REDUCE, 74});  
   
 // State 148  
 \_actionTable.add(148, STAR, {SHIFT, 123});  
 \_actionTable.add(148, SLASH, {SHIFT, 124});  
 \_actionTable.add(148, AMPERSAND, {SHIFT, 125});  
 \_actionTable.addDefault(148, {REDUCE, 81});  
   
 // State 149  
 \_actionTable.add(149, STAR, {SHIFT, 123});  
 \_actionTable.add(149, SLASH, {SHIFT, 124});  
 \_actionTable.add(149, AMPERSAND, {SHIFT, 125});  
 \_actionTable.addDefault(149, {REDUCE, 80});  
   
 // State 150  
 \_actionTable.add(150, STAR, {SHIFT, 123});  
 \_actionTable.add(150, SLASH, {SHIFT, 124});  
 \_actionTable.add(150, AMPERSAND, {SHIFT, 125});  
 \_actionTable.addDefault(150, {REDUCE, 82});  
   
 // State 151  
 \_actionTable.add(151, STAR, {SHIFT, 123});  
 \_actionTable.add(151, SLASH, {SHIFT, 124});  
 \_actionTable.add(151, AMPERSAND, {SHIFT, 125});  
 \_actionTable.addDefault(151, {REDUCE, 83});  
   
 // State 152  
 \_actionTable.addDefault(152, {REDUCE, 85});  
   
 // State 153  
 \_actionTable.addDefault(153, {REDUCE, 86});  
   
 // State 154  
 \_actionTable.addDefault(154, {REDUCE, 87});  
   
 // State 155  
 \_actionTable.add(155, IDENTIFIER, {SHIFT, 51});  
 \_actionTable.add(155, OPEN\_PAREN, {SHIFT, 52});  
 \_actionTable.add(155, STAR, {SHIFT, 53});  
 \_actionTable.add(155, MINUS, {SHIFT, 54});  
 \_actionTable.add(155, BANG, {SHIFT, 55});  
 \_actionTable.add(155, AMPERSAND, {SHIFT, 56});  
 \_actionTable.add(155, INTEGER\_LITERAL, {SHIFT, 57});  
 \_actionTable.add(155, FLOAT\_LITERAL, {SHIFT, 58});  
 \_actionTable.add(155, CHAR\_LITERAL, {SHIFT, 59});  
 \_actionTable.add(155, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(155, MINUS\_MINUS, {SHIFT, 61});  
 \_actionTable.addDefault(155, {REDUCE, 63});  
 \_gotoTable.add(155, EXPR\_LIST, 170);  
 \_gotoTable.add(155, EXPR\_LIST\_NON\_EMPTY, 86);  
 \_gotoTable.add(155, EXPR, 87);  
 \_gotoTable.add(155, LOGICAL\_EXPR, 64);  
 \_gotoTable.add(155, RELATIONAL\_EXPR, 65);  
 \_gotoTable.add(155, ADD\_EXPR, 66);  
 \_gotoTable.add(155, MUL\_EXPR, 67);  
 \_gotoTable.add(155, UNARY\_EXPR, 68);  
 \_gotoTable.add(155, INCREMENT\_EXPR, 69);  
 \_gotoTable.add(155, ADDRESS\_EXPR, 70);  
 \_gotoTable.add(155, DEREFERENCE\_EXPR, 71);  
 \_gotoTable.add(155, PRIMARY\_EXPR, 72);  
   
 // State 156  
 \_actionTable.addDefault(156, {REDUCE, 28});  
   
 // State 157  
 \_actionTable.addDefault(157, {REDUCE, 29});  
   
 // State 158  
 \_actionTable.addDefault(158, {REDUCE, 66});  
   
 // State 159  
 \_actionTable.add(159, CLOSED\_BRACKET, {SHIFT, 171});  
   
 // State 160  
 \_actionTable.addDefault(160, {REDUCE, 15});  
 \_gotoTable.add(160, STMT\_LIST, 172);  
   
 // State 161  
 \_actionTable.add(161, SEMICOLON, {SHIFT, 173});  
   
 // State 162  
 \_actionTable.addDefault(162, {REDUCE, 60});  
   
 // State 163  
 \_actionTable.addDefault(163, {REDUCE, 61});  
   
 // State 164  
 \_actionTable.addDefault(164, {REDUCE, 62});  
   
 // State 165  
 \_actionTable.add(165, KEYWORD\_ELSE, {SHIFT, 174});  
 \_actionTable.addDefault(165, {REDUCE, 44});  
   
 // State 166  
 \_actionTable.addDefault(166, {REDUCE, 46});  
   
 // State 167  
 \_actionTable.add(167, SEMICOLON, {SHIFT, 175});  
   
 // State 168  
 \_actionTable.addDefault(168, {REDUCE, 103});  
   
 // State 169  
 \_actionTable.addDefault(169, {REDUCE, 98});  
   
 // State 170  
 \_actionTable.add(170, CLOSED\_CURLY, {SHIFT, 176});  
   
 // State 171  
 \_actionTable.add(171, EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, PLUS\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, MINUS\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, SLASH\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, STAR\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, AMPERSAND\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, PIPE\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, CARET\_EQUALS, {REDUCE, 33});  
 \_actionTable.add(171, TILDE\_EQUALS, {REDUCE, 33});  
 \_actionTable.addDefault(171, {REDUCE, 98});  
   
 // State 172  
 \_actionTable.add(172, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(172, OPEN\_CURLY, {SHIFT, 28});  
 \_actionTable.add(172, CLOSED\_CURLY, {SHIFT, 177});  
 \_actionTable.add(172, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(172, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(172, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(172, STAR, {SHIFT, 30});  
 \_actionTable.add(172, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(172, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(172, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(172, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(172, TYPE, 35);  
 \_gotoTable.add(172, BASE\_TYPE, 14);  
 \_gotoTable.add(172, STMT, 36);  
 \_gotoTable.add(172, SIMPLE\_STMT, 37);  
 \_gotoTable.add(172, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(172, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(172, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(172, IF\_STMT, 41);  
 \_gotoTable.add(172, WHILE\_STMT, 42);  
 \_gotoTable.add(172, FOR\_STMT, 43);  
   
 // State 173  
 \_actionTable.addDefault(173, {REDUCE, 59});  
   
 // State 174  
 \_actionTable.add(174, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(174, OPEN\_CURLY, {SHIFT, 160});  
 \_actionTable.add(174, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(174, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(174, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(174, STAR, {SHIFT, 30});  
 \_actionTable.add(174, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(174, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(174, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(174, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(174, TYPE, 35);  
 \_gotoTable.add(174, BASE\_TYPE, 14);  
 \_gotoTable.add(174, SIMPLE\_STMT, 161);  
 \_gotoTable.add(174, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(174, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(174, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(174, IF\_STMT, 162);  
 \_gotoTable.add(174, WHILE\_STMT, 163);  
 \_gotoTable.add(174, FOR\_STMT, 164);  
 \_gotoTable.add(174, BODY, 178);  
   
 // State 175  
 \_actionTable.add(175, IDENTIFIER, {SHIFT, 179});  
 \_actionTable.add(175, STAR, {SHIFT, 30});  
 \_actionTable.add(175, PLUS\_PLUS, {SHIFT, 60});  
 \_actionTable.add(175, MINUS\_MINUS, {SHIFT, 61});  
 \_actionTable.addDefault(175, {REDUCE, 55});  
 \_gotoTable.add(175, ASSIGN\_EXPR, 180);  
 \_gotoTable.add(175, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(175, FOR\_UPDATE, 181);  
 \_gotoTable.add(175, INCREMENT\_EXPR, 182);  
   
 // State 176  
 \_actionTable.addDefault(176, {REDUCE, 30});  
   
 // State 177  
 \_actionTable.addDefault(177, {REDUCE, 58});  
   
 // State 178  
 \_actionTable.addDefault(178, {REDUCE, 45});  
   
 // State 179  
 \_actionTable.add(179, OPEN\_BRACKET, {SHIFT, 45});  
 \_actionTable.add(179, PLUS\_PLUS, {SHIFT, 102});  
 \_actionTable.add(179, MINUS\_MINUS, {SHIFT, 103});  
 \_actionTable.addDefault(179, {REDUCE, 32});  
   
 // State 180  
 \_actionTable.addDefault(180, {REDUCE, 56});  
   
 // State 181  
 \_actionTable.add(181, CLOSED\_PAREN, {SHIFT, 183});  
   
 // State 182  
 \_actionTable.addDefault(182, {REDUCE, 57});  
   
 // State 183  
 \_actionTable.add(183, IDENTIFIER, {SHIFT, 27});  
 \_actionTable.add(183, OPEN\_CURLY, {SHIFT, 160});  
 \_actionTable.add(183, KEYWORD\_INT, {SHIFT, 7});  
 \_actionTable.add(183, KEYWORD\_FLOAT, {SHIFT, 8});  
 \_actionTable.add(183, KEYWORD\_CHAR, {SHIFT, 9});  
 \_actionTable.add(183, STAR, {SHIFT, 30});  
 \_actionTable.add(183, KEYWORD\_IF, {SHIFT, 31});  
 \_actionTable.add(183, KEYWORD\_WHILE, {SHIFT, 32});  
 \_actionTable.add(183, KEYWORD\_FOR, {SHIFT, 33});  
 \_actionTable.add(183, KEYWORD\_RET, {SHIFT, 34});  
 \_gotoTable.add(183, TYPE, 35);  
 \_gotoTable.add(183, BASE\_TYPE, 14);  
 \_gotoTable.add(183, SIMPLE\_STMT, 161);  
 \_gotoTable.add(183, VAR\_DECL\_EXPR, 38);  
 \_gotoTable.add(183, ASSIGN\_EXPR, 39);  
 \_gotoTable.add(183, ASSIGN\_TARGET, 40);  
 \_gotoTable.add(183, IF\_STMT, 162);  
 \_gotoTable.add(183, WHILE\_STMT, 163);  
 \_gotoTable.add(183, FOR\_STMT, 164);  
 \_gotoTable.add(183, BODY, 184);  
   
 // State 184  
 \_actionTable.addDefault(184, {REDUCE, 49});  
   
 }  
   
   
 void Parser::initFollowSets()  
 {  
 // \*\*FOLLOW Sets for Non-Terminals\*\*  
 \_followSets[NonTerminal::START] = {SyntaxKind::END\_OF\_FILE};  
 \_followSets[NonTerminal::PROGRAM] = {SyntaxKind::END\_OF\_FILE, SyntaxKind::KEYWORD\_FN};  
 \_followSets[NonTerminal::FUNCTION\_DECL] = {SyntaxKind::END\_OF\_FILE, SyntaxKind::KEYWORD\_FN};  
 \_followSets[NonTerminal::PARAM\_LIST] = {SyntaxKind::CLOSED\_PAREN};  
 \_followSets[NonTerminal::TYPE] = {SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_CURLY};  
 \_followSets[NonTerminal::STMT\_LIST] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_WHILE,  
 SyntaxKind::KEYWORD\_FOR};  
 \_followSets[NonTerminal::PARAM\_LIST\_NON\_EMPTY] = {SyntaxKind::CLOSED\_PAREN, SyntaxKind::COMMA};  
 \_followSets[NonTerminal::PARAM] = {SyntaxKind::CLOSED\_PAREN, SyntaxKind::COMMA};  
 \_followSets[NonTerminal::BASE\_TYPE] = {SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_CURLY, SyntaxKind::OPEN\_BRACKET, SyntaxKind::STAR};  
 \_followSets[NonTerminal::STMT] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_WHILE,  
 SyntaxKind::KEYWORD\_FOR};  
 \_followSets[NonTerminal::SIMPLE\_STMT] = {SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::IF\_STMT] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_ELSE,  
 SyntaxKind::KEYWORD\_WHILE, SyntaxKind::KEYWORD\_FOR};  
 \_followSets[NonTerminal::WHILE\_STMT] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_ELSE,  
 SyntaxKind::KEYWORD\_WHILE, SyntaxKind::KEYWORD\_FOR};  
 \_followSets[NonTerminal::FOR\_STMT] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_ELSE,  
 SyntaxKind::KEYWORD\_WHILE, SyntaxKind::KEYWORD\_FOR};  
 \_followSets[NonTerminal::VAR\_DECL\_EXPR] = {SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::ASSIGN\_EXPR] = {SyntaxKind::CLOSED\_PAREN, SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::EXPR\_OPT] = {SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::INIT\_OPT] = {SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::ASSIGN\_VALUE] = {SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::EXPR\_LIST] = {SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY};  
 \_followSets[NonTerminal::ASSIGN\_TARGET] = {  
 SyntaxKind::EQUALS, SyntaxKind::PLUS\_EQUALS, SyntaxKind::MINUS\_EQUALS, SyntaxKind::SLASH\_EQUALS,  
 SyntaxKind::STAR\_EQUALS, SyntaxKind::AMPERSAND\_EQUALS, SyntaxKind::PIPE\_EQUALS, SyntaxKind::CARET\_EQUALS,  
 SyntaxKind::TILDE\_EQUALS};  
 \_followSets[NonTerminal::ASSIGN\_OP] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR};  
 \_followSets[NonTerminal::CONDITION\_OP] = {SyntaxKind::CLOSED\_PAREN};  
 \_followSets[NonTerminal::BODY] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_ELSE,  
 SyntaxKind::KEYWORD\_WHILE, SyntaxKind::KEYWORD\_FOR};  
 \_followSets[NonTerminal::FOR\_INIT] = {SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::FOR\_UPDATE] = {SyntaxKind::CLOSED\_PAREN};  
 \_followSets[NonTerminal::INCREMENT\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::EXPR\_LIST\_NON\_EMPTY] = {SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA};  
 \_followSets[NonTerminal::LOGICAL\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::ADDRESS\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::DEREFERENCE\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::RELATIONAL\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::ADD\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::MUL\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::STAR, SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::UNARY\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::STAR, SyntaxKind::SEMICOLON};  
 \_followSets[NonTerminal::PRIMARY\_EXPR] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::STAR, SyntaxKind::SEMICOLON};  
   
 // \*\*FOLLOW Sets for Terminals\*\*  
 // Common set for tokens that start expressions (used by operators)  
 std::unordered\_set<SyntaxKind> exprStarters = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::INTEGER\_LITERAL, SyntaxKind::FLOAT\_LITERAL,  
 SyntaxKind::CHAR\_LITERAL, SyntaxKind::STRING\_LITERAL, SyntaxKind::STAR, SyntaxKind::AMPERSAND,  
 SyntaxKind::BANG, SyntaxKind::PLUS\_PLUS, SyntaxKind::MINUS\_MINUS, SyntaxKind::MINUS};  
   
 // Binary operators (e.g., +, -, \*, /, ||, &&, ==, etc.)  
 \_followTerminalsSets[SyntaxKind::PIPE\_PIPE] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::AMPERSAND\_AMPERSAND] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::PLUS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::MINUS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::PIPE] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::CARET] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::SLASH] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::STAR] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::EQUALS\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::BANG\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::LESS\_THAN] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::GREATER\_THAN] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::LESS\_THAN\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::GREATER\_THAN\_EQUALS] = exprStarters;  
   
 // Assignment operators (e.g., =, +=, -=, etc.)  
 \_followTerminalsSets[SyntaxKind::EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::PLUS\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::MINUS\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::SLASH\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::STAR\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::AMPERSAND\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::PIPE\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::CARET\_EQUALS] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::TILDE\_EQUALS] = exprStarters;  
   
 // Unary operators  
 \_followTerminalsSets[SyntaxKind::AMPERSAND] = {SyntaxKind::IDENTIFIER}; // Address-of  
 \_followTerminalsSets[SyntaxKind::BANG] = exprStarters; // Logical not  
 \_followTerminalsSets[SyntaxKind::MINUS] = exprStarters; // Unary minus  
   
 // Increment/Decrement operators  
 \_followTerminalsSets[SyntaxKind::PLUS\_PLUS] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA,  
 SyntaxKind::CLOSED\_BRACKET, SyntaxKind::SEMICOLON};  
 \_followTerminalsSets[SyntaxKind::MINUS\_MINUS] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA,  
 SyntaxKind::CLOSED\_BRACKET, SyntaxKind::SEMICOLON};  
   
 // Literals  
 std::unordered\_set<SyntaxKind> literalFollow = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON, SyntaxKind::PLUS, SyntaxKind::MINUS, SyntaxKind::STAR, SyntaxKind::SLASH,  
 SyntaxKind::PIPE, SyntaxKind::AMPERSAND, SyntaxKind::CARET, SyntaxKind::PIPE\_PIPE, SyntaxKind::AMPERSAND\_AMPERSAND,  
 SyntaxKind::EQUALS\_EQUALS, SyntaxKind::BANG\_EQUALS, SyntaxKind::LESS\_THAN, SyntaxKind::GREATER\_THAN,  
 SyntaxKind::LESS\_THAN\_EQUALS, SyntaxKind::GREATER\_THAN\_EQUALS};  
 \_followTerminalsSets[SyntaxKind::INTEGER\_LITERAL] = literalFollow;  
 \_followTerminalsSets[SyntaxKind::FLOAT\_LITERAL] = literalFollow;  
 \_followTerminalsSets[SyntaxKind::CHAR\_LITERAL] = literalFollow;  
 \_followTerminalsSets[SyntaxKind::STRING\_LITERAL] = literalFollow;  
   
 // Keywords  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_FN] = {SyntaxKind::IDENTIFIER};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_INT] = {SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_CURLY, SyntaxKind::OPEN\_BRACKET, SyntaxKind::STAR};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_FLOAT] = {SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_CURLY, SyntaxKind::OPEN\_BRACKET, SyntaxKind::STAR};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_CHAR] = {SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_CURLY, SyntaxKind::OPEN\_BRACKET, SyntaxKind::STAR};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_RET] = exprStarters; // Followed by optional expression  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_IF] = {SyntaxKind::OPEN\_PAREN};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_ELSE] = {  
 SyntaxKind::OPEN\_CURLY, SyntaxKind::IDENTIFIER, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_WHILE,  
 SyntaxKind::KEYWORD\_FOR};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_WHILE] = {SyntaxKind::OPEN\_PAREN};  
 \_followTerminalsSets[SyntaxKind::KEYWORD\_FOR] = {SyntaxKind::OPEN\_PAREN};  
   
 // Punctuation  
 \_followTerminalsSets[SyntaxKind::OPEN\_PAREN] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::CLOSED\_PAREN] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON, SyntaxKind::PLUS, SyntaxKind::MINUS, SyntaxKind::STAR, SyntaxKind::SLASH,  
 SyntaxKind::PIPE, SyntaxKind::AMPERSAND, SyntaxKind::CARET, SyntaxKind::PIPE\_PIPE, SyntaxKind::AMPERSAND\_AMPERSAND,  
 SyntaxKind::EQUALS\_EQUALS, SyntaxKind::BANG\_EQUALS, SyntaxKind::LESS\_THAN, SyntaxKind::GREATER\_THAN,  
 SyntaxKind::LESS\_THAN\_EQUALS, SyntaxKind::GREATER\_THAN\_EQUALS};  
 \_followTerminalsSets[SyntaxKind::OPEN\_CURLY] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_WHILE,  
 SyntaxKind::KEYWORD\_FOR};  
 \_followTerminalsSets[SyntaxKind::CLOSED\_CURLY] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_ELSE,  
 SyntaxKind::KEYWORD\_WHILE, SyntaxKind::KEYWORD\_FOR};  
 \_followTerminalsSets[SyntaxKind::OPEN\_BRACKET] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::CLOSED\_BRACKET] = {  
 SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA, SyntaxKind::CLOSED\_BRACKET,  
 SyntaxKind::SEMICOLON, SyntaxKind::PLUS, SyntaxKind::MINUS, SyntaxKind::STAR, SyntaxKind::SLASH,  
 SyntaxKind::PIPE, SyntaxKind::AMPERSAND, SyntaxKind::CARET, SyntaxKind::PIPE\_PIPE, SyntaxKind::AMPERSAND\_AMPERSAND,  
 SyntaxKind::EQUALS\_EQUALS, SyntaxKind::BANG\_EQUALS, SyntaxKind::LESS\_THAN, SyntaxKind::GREATER\_THAN,  
 SyntaxKind::LESS\_THAN\_EQUALS, SyntaxKind::GREATER\_THAN\_EQUALS};  
 \_followTerminalsSets[SyntaxKind::COMMA] = exprStarters;  
 \_followTerminalsSets[SyntaxKind::SEMICOLON] = {  
 SyntaxKind::IDENTIFIER, SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_CURLY, SyntaxKind::CLOSED\_CURLY,  
 SyntaxKind::INTEGER\_LITERAL, SyntaxKind::STAR, SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT,  
 SyntaxKind::KEYWORD\_CHAR, SyntaxKind::KEYWORD\_RET, SyntaxKind::KEYWORD\_IF, SyntaxKind::KEYWORD\_WHILE,  
 SyntaxKind::KEYWORD\_FOR};  
 \_followTerminalsSets[SyntaxKind::RIGHT\_ARROW] = {SyntaxKind::KEYWORD\_INT, SyntaxKind::KEYWORD\_FLOAT, SyntaxKind::KEYWORD\_CHAR};  
   
 // Identifier  
 \_followTerminalsSets[SyntaxKind::IDENTIFIER] = {  
 SyntaxKind::OPEN\_PAREN, SyntaxKind::OPEN\_BRACKET, SyntaxKind::PLUS\_PLUS, SyntaxKind::MINUS\_MINUS,  
 SyntaxKind::EQUALS, SyntaxKind::PLUS\_EQUALS, SyntaxKind::MINUS\_EQUALS, SyntaxKind::SLASH\_EQUALS,  
 SyntaxKind::STAR\_EQUALS, SyntaxKind::AMPERSAND\_EQUALS, SyntaxKind::PIPE\_EQUALS, SyntaxKind::CARET\_EQUALS,  
 SyntaxKind::TILDE\_EQUALS, SyntaxKind::CLOSED\_PAREN, SyntaxKind::CLOSED\_CURLY, SyntaxKind::COMMA,  
 SyntaxKind::CLOSED\_BRACKET, SyntaxKind::SEMICOLON, SyntaxKind::PLUS, SyntaxKind::MINUS, SyntaxKind::STAR,  
 SyntaxKind::SLASH, SyntaxKind::PIPE, SyntaxKind::AMPERSAND, SyntaxKind::CARET, SyntaxKind::PIPE\_PIPE,  
 SyntaxKind::AMPERSAND\_AMPERSAND, SyntaxKind::EQUALS\_EQUALS, SyntaxKind::BANG\_EQUALS, SyntaxKind::LESS\_THAN,  
 SyntaxKind::GREATER\_THAN, SyntaxKind::LESS\_THAN\_EQUALS, SyntaxKind::GREATER\_THAN\_EQUALS};  
 }

## parser.cpp

#include "parser.hpp"  
 #include "../errors/errors.hpp"  
 #include "../nodes/nodes.hpp"  
 #include "stackItem/stackItem.hpp"  
 #include "../token/token.hpp"  
 #include "grammerSymbol/grammerSymbol.hpp"  
 #include "productionRule/productionRule.hpp"  
 #include "../symbolTable/functionEntry/functionEntry.hpp"  
 #include <vector>  
 #include <iostream>  
   
 // #define PARSER\_DEBUG  
   
 using namespace std;  
   
 Parser::Parser(vector<SyntaxToken \*> tokens, int numOfStates, ErrorHandler \*handler, SemanticAnalyzer \*semanticAnalyser)  
 : \_actionTable(numOfStates), \_gotoTable(numOfStates), \_semanticAnalyzer(semanticAnalyser), \_rules(), \_stack(), \_errorHandler(handler), \_tokens(tokens), \_cursor(0)  
 {  
 \_stack.push(StackItem{0, new NonTerminalNode(NonTerminal::START)});  
 initProductionRules();  
 fillTables();  
 initFollowSets();  
 }  
   
 SyntaxToken \*Parser::getNextToken()  
 {  
 \_cursor++;  
 return peek(0);  
 }  
   
 SyntaxToken \*Parser::peek(int index)  
 {  
 if (\_cursor + index >= \_tokens.size())  
 {  
 SyntaxToken \*resToken = new SyntaxToken();  
 resToken->kind = SyntaxKind::END\_OF\_FILE;  
 return resToken;  
 }  
   
 return \_tokens[\_cursor + index];  
 }  
   
 SyntaxToken \*Parser::getCurrToken()  
 {  
 return peek(0);  
 }  
   
 void Parser::addProductionRule(productionRule rule)  
 {  
 \_rules.push\_back(rule);  
 }  
   
 action Parser::getCurrAction()  
 {  
 return \_actionTable.get(\_stack.top().state, peek(0)->kind);  
 }  
   
 void Parser::shift(action currAction)  
 {  
 int state = currAction.num;  
 SyntaxToken \*token = getCurrToken();  
   
 #ifdef PARSER\_DEBUG  
 cout << "Shifting to state " << currAction.num << " with token " << syntaxTokenToString(\*token) << endl;  
 #endif  
   
 // Create a new terminalNode  
 ASTNode \*node = new TerminalNode(token);  
   
 // assign the node type for semantic analysis  
 \_semanticAnalyzer->assignNodeType(node);  
   
 // Push to stack  
 \_stack.push(StackItem{state, node});  
   
 // Update current state  
 \_currState = state;  
   
 // update the scope  
 \_semanticAnalyzer -> updateScope(getCurrToken());  
   
 // proceed to next token  
 getNextToken();  
 }  
   
 void Parser::reduce(action currAction)  
 {  
 int productionRuleNum = currAction.num;  
   
 #ifdef PARSER\_DEBUG  
 cout << "Reducing with rule " << productionRuleNum << endl;  
 #endif  
   
 productionRule rule = \_rules[productionRuleNum];  
   
 #ifdef PARSER\_DEBUG  
 cout << rule.toString() << endl;  
 #endif  
   
 // Create a new nonTerminalNode  
 NonTerminalNode \*node = new NonTerminalNode(rule.getLeft());  
   
 if ((rule.getType(0) == GrammarSymbolType::TERMINAL) && (rule.getTerminal(0) == EPSILON)) // if rule is empty return without adding children  
 {  
 \_stack.push(StackItem{\_gotoTable.get(\_stack.top().state, rule.getLeft()), node});  
 }  
 else  
 {  
 reduceStatmentToNode(node, rule);  
   
 // Push to stack  
 int currentState = \_stack.top().state;  
 \_stack.push(StackItem{\_gotoTable.get(currentState, rule.getLeft()), node});  
   
 // Update current state  
 \_currState = currentState;  
 }  
   
 \_semanticAnalyzer->assignNodeType(node); // assign the node type for semantic analysis  
 \_semanticAnalyzer-> updateSybolTable(\_stack.top().node); // update the symbol table with the new node  
 }  
   
 void Parser::reduceStatmentToNode(NonTerminalNode \*node, productionRule rule)  
 {  
 // Pop from stack and create the new node  
 for (int i = rule.getNumOfRightSideSymbols() - 1; i >= 0; i--)  
 {  
 node->AddChildToFront(\_stack.top().node);  
 \_stack.pop();  
 }  
 }  
   
   
   
 ASTNode \*Parser::parse()  
 {  
 action currAction;  
 bool panic = false;  
   
 do  
 {  
 #ifdef PARSER\_DEBUG  
 cout << endl;  
 printStack();  
 cout << endl;  
 #endif  
   
 int state = \_stack.top().state;  
   
 currAction = getCurrAction();  
   
 #ifdef PARSER\_DEBUG  
 cout << "state:" << state << " token:" << syntaxTokenToString(\*peek(0)) << " Action: " << actionTypeToString(currAction) << endl;  
 #endif  
   
 if (currAction.type == actionType::REDUCE)  
 {  
 reduce(currAction);  
 panic = false; // reset panic mode  
 }  
 else if (currAction.type == actionType::SHIFT)  
 {  
 shift(currAction);  
 panic = false; // reset panic mode  
 }  
 else if (currAction.type == actionType::DEFAULT) // error  
 {  
 if (!panic)  
 {  
 panic = true; // enter panic mode  
 reportParsingError();  
 }  
   
 getNextToken();  
   
 if (getCurrToken()->kind == SyntaxKind::END\_OF\_FILE)  
 {  
 currAction.type = actionType::ACCEPT; // end of file token  
 }  
 }  
   
 } while (currAction.type != actionType::ACCEPT);  
   
 \_semanticAnalyzer->checkForMainFunction(); // check if the main function is declared  
   
 \_stack.pop(); // pop the end of file token  
   
 #ifdef PARSER\_DEBUG  
 PrintParseTree(\_stack.top().node);  
 #endif  
   
 return \_stack.top().node;  
 }  
   
 void Parser::reportParsingError()  
 {  
 // adding error to the error handler  
 // with the expected token  
 ASTNode \*node = \_stack.top().node;  
 SyntaxKind recoveryKind;  
 if (node->GetType() == GrammarSymbolType::TERMINAL)  
 {  
 recoveryKind = getTerminalFollowSetItem(((TerminalNode \*)node)->getToken()->kind);  
 \_errorHandler->addError(new SyntacticError(peek(0), recoveryKind));  
 }  
 else  
 {  
 recoveryKind = getNonTerminalFollowSetItem(((NonTerminalNode \*)node)->getNonTerminalKind());  
 \_errorHandler->addError(new SyntacticError(peek(0), recoveryKind));  
 }  
 }  
   
 SyntaxKind Parser::getNonTerminalFollowSetItem(NonTerminal nt)  
 {  
 SyntaxKind res = SyntaxKind::UNEXPECTED\_TOKEN;  
   
 auto it = \_followSets.find(nt);  
 if (it != \_followSets.end())  
 {  
 res = \*it->second.begin();  
 }  
   
 return res; // return the first item in the follow set  
 }  
   
 SyntaxKind Parser::getTerminalFollowSetItem(SyntaxKind kind)  
 {  
 SyntaxKind res = SyntaxKind::UNEXPECTED\_TOKEN;  
   
 auto it = \_followTerminalsSets.find(kind);  
 if (it != \_followTerminalsSets.end())  
 {  
 res = \*it->second.begin();  
 }  
   
 return res; // return the first item in the follow set  
 }  
   
 void Parser::printStack()  
 {  
 if (\_stack.empty())  
 {  
 cout << "[Empty Stack]" << endl;  
 return;  
 }  
   
 stack<StackItem> tempStack;  
 StackItem item;  
   
 while (!\_stack.empty())  
 {  
 item = \_stack.top();  
 tempStack.push(item);  
 \_stack.pop();  
 }  
   
 while (!tempStack.empty())  
 {  
 item = tempStack.top();  
 cout << stackItemToString(item) << ", ";  
 tempStack.pop();  
 \_stack.push(item);  
 }  
   
 cout << " ->" << endl;  
 }  
   
 void Parser::printRules()  
 {  
 for (int i = 0; i < \_rules.size(); i++)  
 {  
 cout << "\e[0;31mRule " << i << "\e[0;37m : " << \_rules[i].toString() << endl;  
 }  
 }  
   
 void Parser::printFollowSet()  
 {  
 for (int i = 0; i < \_rules.size(); i++)  
 {  
 NonTerminal nt = \_rules[i].getLeft();  
 cout << "follow(" << nonTerminalToString(nt) << ") = {";  
   
 int j = \_followSets[\_rules[i].getLeft()].size(); // size of follow set  
 for (const SyntaxKind &terminal : \_followSets[nt])  
 {  
 cout << syntaxKindToString(terminal);  
 if (j != 1)  
 cout << ", ";  
   
 j--;  
 }  
   
 cout << "}" << endl;  
 }  
   
 for (int i = 0; i < SYNTAX\_KIND\_COUNT; i++)  
 {  
 SyntaxKind kind = (SyntaxKind)i;  
 cout << "follow(" << syntaxKindToString(kind) << ") = {";  
   
 int j = \_followTerminalsSets[kind].size(); // size of follow set  
 for (const SyntaxKind &terminal : \_followTerminalsSets[kind])  
 {  
 cout << syntaxKindToString(terminal);  
 if (j != 1)  
 cout << ", ";  
   
 j--;  
 }  
   
 cout << "}" << endl;  
 }  
 }

## parser.hpp

#ifndef PARSER  
 #define PARSER  
   
 #include "productionRule/productionRule.hpp"  
 #include "parseTable/gotoTable/gotoTable.hpp"  
 #include "parseTable/actionTable/actionTable.hpp"  
 #include "productionRule/productionRule.hpp"  
 #include "stackItem/stackItem.hpp"  
 #include "../nodes/nodes.hpp"  
 #include "../errorHandler/errorHandler.hpp"  
 #include "../errors/errors.hpp"  
 #include "../token/token.hpp"  
 #include "symbolTable/symbolTable.hpp"  
 #include "../scope/scope.hpp"  
 #include "../semantic/semantic.hpp"  
 #include <stack>  
 #include <string>  
 #include <vector>  
 #include <sstream>  
 #include <algorithm>  
 #include <unordered\_map>  
 #include <unordered\_set>  
 #include <iostream>  
   
 extern string nonTerminalKindToString[];  
   
 class Parser  
 {  
 private:  
 // parse table  
 ActionTable \_actionTable;  
 GotoTable \_gotoTable;  
 stack<StackItem> \_stack;  
 int \_currState;  
   
 action getCurrAction();  
 void shift(action currAction);  
 void reduce(action currAction);  
 void reduceStatmentToNode(NonTerminalNode \*node, productionRule rule);  
   
 // init functions  
 void initProductionRules();  
 void fillTables();  
   
 // Follow sets  
 unordered\_map<NonTerminal, unordered\_set<SyntaxKind>> \_followSets;  
 unordered\_map<SyntaxKind, unordered\_set<SyntaxKind>> \_followTerminalsSets;  
 SyntaxKind getNonTerminalFollowSetItem(NonTerminal nt);  
 SyntaxKind getTerminalFollowSetItem(SyntaxKind kind);  
   
 void initFollowSets();  
   
 // Navigation and helpers  
 vector<SyntaxToken \*> \_tokens;  
 vector<productionRule> \_rules;  
 int \_cursor;  
   
 SyntaxToken \*getNextToken();  
 SyntaxToken \*getCurrToken();  
 SyntaxToken \*peek(int index);  
 void addProductionRule(productionRule rule);  
   
 // error handling  
 ErrorHandler \*\_errorHandler;  
   
 void reportParsingError();  
   
 // semantic analysis  
 SemanticAnalyzer \*\_semanticAnalyzer;  
 void assignNodeType(ASTNode \*node);  
   
 public:  
 Parser(vector<SyntaxToken \*> tokens, int numOfStates, ErrorHandler \*handler, SemanticAnalyzer \*semanticAnalyzer);  
   
 ASTNode \*parse();  
   
 // Debugging  
 void printStack();  
 void printRules();  
 void printFollowSet();  
 };  
   
 #endif

## action.cpp

#include "action.hpp"  
   
 string actionTypeToString(action type)  
 {  
 stringstream res;  
 switch (type.type)  
 {  
 case actionType::SHIFT:  
 res << "s" << type.num;  
 break;  
 case actionType::REDUCE:  
 res << "r" << type.num;  
 break;  
 case actionType::ACCEPT:  
 res << "acc";  
 break;  
 case actionType::DEFAULT:  
 res << "DEFAULT";  
 break;  
 default:  
 res << "UNKNOWN";  
 break;  
 }  
   
 return res.str();  
 }

## action.hpp

#ifndef \_\_ACTION  
 #define \_\_ACTION  
 #include <string>  
 #include <sstream>  
   
 using namespace std;  
   
 enum actionType  
 {  
 SHIFT,  
 REDUCE,  
 ACCEPT,  
 DEFAULT,  
 };  
   
 struct action  
 {  
 actionType type;  
 int num;  
 };  
   
 string actionTypeToString(action type);  
 #endif

## actionTable.cpp

#include "actionTable.hpp"  
 #include <map>  
 #include <vector>  
 #include "../action/action.hpp"  
 #include "../../../nodes/nodes.hpp"  
 #include "../../../token/token.hpp"  
 #include "../../grammerSymbol/grammerSymbol.hpp"  
   
 using namespace std;  
   
 ActionTable ::ActionTable(int numOfStates) : \_numOfStates(numOfStates)  
 {  
 \_table = new action \*[\_numOfStates];  
 \_defaultActions = new action[\_numOfStates];  
 for (int i = 0; i < \_numOfStates; i++)  
 {  
 \_defaultActions[i] = {actionType::DEFAULT, -1};  
 \_table[i] = new action[SyntaxKind::SYNTAX\_KIND\_COUNT];  
 for (int j = 0; j < SyntaxKind::SYNTAX\_KIND\_COUNT; j++)  
 {  
 \_table[i][j].type = actionType::DEFAULT;  
 \_table[i][j].num = -1;  
 }  
 }  
   
   
 }  
   
 ActionTable ::~ActionTable()  
 {  
 for (int i = 0; i < \_numOfStates; i++)  
 {  
 delete[] \_table[i];  
 }  
   
 delete[] \_defaultActions;  
 delete[] \_table;  
 }  
   
 void ActionTable ::add(int state, SyntaxKind terminal, action act)  
 {  
 if (state >= \_numOfStates || terminal >= SyntaxKind::SYNTAX\_KIND\_COUNT)  
 {  
 runtime\_error("Invalid state or symbol");  
 }  
   
 else if (\_table[state][terminal].type == actionType::DEFAULT)  
 {  
 \_table[state][terminal] = act;  
 }  
   
 else  
 {  
 runtime\_error("Conflict in action table");  
 }  
 }  
   
 void ActionTable::addDefault(int state, action act)  
 {  
 if (state >= \_numOfStates)  
 {  
 runtime\_error("Invalid state");  
 }  
   
 else if (\_defaultActions[state].num == -1)  
 {  
 \_defaultActions[state] = act;  
 }  
   
 else  
 {  
 runtime\_error("Conflict in action table");  
 }  
 }  
   
 action ActionTable ::get(int state, SyntaxKind terminal)  
 {  
 if (state >= \_numOfStates || terminal >= SyntaxKind::SYNTAX\_KIND\_COUNT)  
 {  
 runtime\_error("Invalid state or terminal");  
 }  
   
 if(\_table[state][terminal].type == DEFAULT)  
 {  
 return \_defaultActions[state];  
 }  
   
 return \_table[state][terminal];  
 }

## actionTable.hpp

#ifndef \_\_ACTION\_TABLE  
 #define \_\_ACTION\_TABLE  
   
 #include "../action/action.hpp"  
 #include "../../../token/token.hpp"  
 #include "../../grammerSymbol/grammerSymbol.hpp"  
   
 class ActionTable  
 {  
 private:  
 action \*\*\_table;  
 action \*\_defaultActions;  
 int \_numOfStates;  
   
 public:  
 ActionTable(int numOfStates);  
 ~ActionTable();  
 void add(int state, SyntaxKind terminal, action act);  
 void addDefault(int state, action act);  
 action get(int state, SyntaxKind terminal);  
 };  
   
 #endif

## gotoTable.cpp

#include "gotoTable.hpp"  
 #include "../../../token/token.hpp"  
 #include "../../grammerSymbol/grammerSymbol.hpp"  
 #include <map>  
 #include <vector>  
 #include <iostream>  
   
 using namespace std;  
   
 GotoTable::GotoTable(int numOfStates) : \_numOfStates(numOfStates)  
 {  
 \_table = new int \*[\_numOfStates];  
 for (int i = 0; i < \_numOfStates; i++)  
 {  
 \_table[i] = new int[NonTerminal::NON\_TERMINAL\_COUNT];  
 for (int j = 0; j < NonTerminal::NON\_TERMINAL\_COUNT; j++)  
 {  
 \_table[i][j] = -1;  
 }  
 }  
 }  
   
 GotoTable::~GotoTable()  
 {  
 }  
   
 // adds a new entry to the table  
 void GotoTable::add(int startState, NonTerminal nt, int endState)  
 {  
 if (nt >= NonTerminal::NON\_TERMINAL\_COUNT || startState >= \_numOfStates || endState >= \_numOfStates)  
 {  
 cerr << "Invalid input on gotoTable::add() function" << endl;  
 exit(1);  
 }  
 else if (\_table[startState][nt] == -1)  
 {  
 \_table[startState][nt] = endState;  
 }  
 else  
 {  
 cerr << "Conflict in goto table" << endl;  
 exit(1);  
 }  
 }  
   
 // gets the end state of a non terminal in a given state  
 int GotoTable::get(int state, NonTerminal nt)  
 {  
 if (nt >= NonTerminal::NON\_TERMINAL\_COUNT || state >= \_numOfStates)  
 {  
 runtime\_error("Invalid non terminal or state");  
 }  
   
 return \_table[state][nt];  
 }

## gotoTable.hpp

#ifndef \_\_GOTO\_TABLE  
 #define \_\_GOTO\_TABLE  
   
 #include "../../../token/token.hpp"  
 #include "../../grammerSymbol/grammerSymbol.hpp"  
   
 #include <map>  
 #include <vector>  
   
 class GotoTable  
 {  
 private:  
 int \*\*\_table;  
   
 public:  
 int \_numOfStates;  
   
 GotoTable(int numOfStates);  
 ~GotoTable();  
 void add(int startState, NonTerminal nt, int endState);  
 int get(int state, NonTerminal nt);  
 };  
   
 #endif

## productionRule.cpp

#include "productionRule.hpp"  
 #include "../GrammerSymbol/grammerSymbol.hpp"  
 #include "../../token/token.hpp"  
 #include <iostream>  
 #include <sstream>  
 #include <vector>  
 #include <map>  
   
 using namespace std;  
   
 productionRule::productionRule(NonTerminal left) : \_left(left), \_numOfRightSideSymbols(0) {}  
   
 productionRule::productionRule() :productionRule(NonTerminal::PROGRAM) {}  
   
 productionRule::~productionRule() {}  
   
 productionRule& productionRule::addSymbol(SyntaxKind terminal)  
 {  
 \_rightSideSymbols.push\_back(terminal);  
 \_rightSideTypes.push\_back(GrammarSymbolType::TERMINAL);  
 \_numOfRightSideSymbols++;  
   
 return \*this;  
 }  
   
 productionRule& productionRule::addSymbol(NonTerminal nonTerminal)  
 {  
 \_rightSideSymbols.push\_back(nonTerminal);  
 \_rightSideTypes.push\_back(GrammarSymbolType::NON\_TERMINAL);  
 \_numOfRightSideSymbols++;  
   
 return \*this;  
 }  
   
 productionRule& productionRule::addSymbol()  
 {  
 return addSymbol(SyntaxKind::EPSILON);  
 }  
   
   
   
 SyntaxKind productionRule::getTerminal(int index)  
 {  
 if (index >= \_numOfRightSideSymbols)  
 {  
 cerr << ("Index out of range");  
 exit(1);  
 }  
   
 if (\_rightSideTypes[index] != GrammarSymbolType::TERMINAL)  
 {  
 cerr << ("Symbol at index is not a terminal");  
 exit(1);  
 }  
   
 return (SyntaxKind)\_rightSideSymbols[index];  
 }  
   
 NonTerminal productionRule::getNonTerminal(int index)  
 {  
 if (index >= \_numOfRightSideSymbols)  
 {  
 cerr << ("Index out of range");  
 exit(1);  
 }  
   
 if (\_rightSideTypes[index] != GrammarSymbolType::NON\_TERMINAL)  
 {  
 cerr << ("Symbol at index is not a non terminal");  
 exit(1);  
 }  
   
 return (NonTerminal)\_rightSideSymbols[index];  
 }  
   
 GrammarSymbolType productionRule::getType(int index)  
 {  
 if (index >= \_numOfRightSideSymbols)  
 {  
 runtime\_error("Index out of range");  
 }  
   
 return \_rightSideTypes[index];  
 }  
   
 int productionRule::getNumOfRightSideSymbols()  
 {  
 return \_numOfRightSideSymbols;  
 }  
   
 NonTerminal productionRule::getLeft()  
 {  
 return \_left;  
 }  
   
 void productionRule::setLeft(NonTerminal left)  
 {  
 \_left = left;  
 }  
   
 void productionRule::reset()  
 {  
 \_numOfRightSideSymbols = 0;  
 \_rightSideSymbols.clear();  
 \_rightSideTypes.clear();  
 }  
   
 string productionRule::toString()  
 {  
 stringstream str;  
 str << nonTerminalToString(\_left)  
 << " \e[0;33m=>\033[0m";  
   
 for (int i = 0; i < \_numOfRightSideSymbols; i++)  
 {  
 if (\_rightSideTypes[i] == GrammarSymbolType::TERMINAL)  
 {  
 str << " " << syntaxKindToString((SyntaxKind)(\_rightSideSymbols[i]));  
 }  
 else  
 {  
 str << " " << nonTerminalToString((NonTerminal)\_rightSideSymbols[i]);  
 }  
 }  
   
 return str.str();  
 }

## productionRule.hpp

#ifndef \_\_PRODUCTION\_RULE  
 #define \_\_PRODUCTION\_RULE  
   
 #include "../../token/token.hpp"  
 #include "../grammerSymbol/grammerSymbol.hpp"  
 #include <vector>  
   
 using namespace std;  
   
 class productionRule  
 {  
 private:  
 // left side of the production rule  
 NonTerminal \_left;  
   
 // right side of the production rule  
 int \_numOfRightSideSymbols;  
 vector<int> \_rightSideSymbols;  
 vector<GrammarSymbolType> \_rightSideTypes;  
   
 public:  
 productionRule(NonTerminal left);  
 productionRule();  
 ~productionRule();  
 productionRule& addSymbol(SyntaxKind terminal);  
 productionRule& addSymbol(NonTerminal nonTerminal);  
 productionRule& addSymbol();  
 NonTerminal getNonTerminal(int index);  
 SyntaxKind getTerminal(int index);  
 GrammarSymbolType getType(int index);  
 int getNumOfRightSideSymbols();  
 NonTerminal getLeft();  
 void setLeft(NonTerminal left);  
 void reset();  
 string toString();  
 };  
   
 #endif

## stackItem.cpp

#include "stackItem.hpp"  
 #include "../../nodes/nodes.hpp"  
 #include <string>  
 #include <sstream>  
 #include <iostream>  
   
 using namespace std;  
   
 string stackItemToString(StackItem item)  
 {  
 stringstream res;  
 res << "(" << ""<<AstNodeToString(item.node)<<"" << " | " << item.state << ")";  
 return res.str();  
 }  
   
 void printStackItem(StackItem item)  
 {  
 cout << stackItemToString(item) << endl;  
 }

## stackItem.hpp

#ifndef \_\_STACK\_ITEM  
 #define \_\_STACK\_ITEM  
 #include <string>  
   
 #include "../../nodes/nodes.hpp"  
   
 using namespace std;  
   
 struct StackItem  
 {  
 int state;  
 ASTNode \*node;  
 };  
   
 string stackItemToString(StackItem item);  
 void printStackItem(StackItem item);  
 #endif

## semantic.cpp

#include "semantic.hpp"  
 #include "../symbolTable/symbolTable.hpp"  
 #include "../token/token.hpp"  
 #include <vector>  
   
 using namespace std;  
   
 std::map<SyntaxKind, baseType> assignTerminal = {  
 {KEYWORD\_INT, INT},  
 {KEYWORD\_CHAR, CHAR},  
 {KEYWORD\_FLOAT, FLOAT},  
 {INTEGER\_LITERAL, INT},  
 {CHAR\_LITERAL, CHAR},  
 {FLOAT\_LITERAL, FLOAT}};  
   
 SemanticAnalyzer::SemanticAnalyzer(ErrorHandler \*errorHandler, SymbolTable \*symbolTable) : \_errorHandler(errorHandler), \_symbolTable(symbolTable)  
 {  
 initAssignActions();  
 }  
   
 void SemanticAnalyzer::addFunctionNodeToSymbolTable(NonTerminalNode \*funcDeclNode)  
 {  
 /// if we encounter a function declaration we need to procces it correctly in order to update the symbol table  
   
 // get the second child value (name)  
 TerminalNode \*nameNode = (TerminalNode \*)(funcDeclNode->GetChildren()[1]);  
 string name = ((TerminalNode \*)(funcDeclNode->GetChildren()[1]))->getToken()->val;  
   
 // check if the function already exists in the symbol table  
 functionEntry \*funcEntry = \_symbolTable->getFunction(name);  
 if (funcEntry != nullptr)  
 {  
 \_errorHandler->addError(new semanticError("function already declared", nameNode->getToken()));  
 }  
 else  
 {  
 // get the seventh child value (the type)  
 valType funcVarType = createVarDeclExprType((NonTerminalNode \*)(funcDeclNode->GetChildren()[6]));  
   
 // get the forth child value (the types of the function parameters)  
 vector<valType> paramTypes = createFunctionParamTypes((NonTerminalNode \*)(funcDeclNode->GetChildren()[3]));  
   
 // create the entry  
 functionEntry \*funcEntry = new functionEntry(name, funcVarType, paramTypes);  
   
 // check return statements  
 checkReturnStatements(funcEntry);  
   
 // add the current root scope as their scope  
 funcEntry->setInnerScope(\_currRootScope);  
   
 // and finally, add the function to the table  
 \_symbolTable->addFunction(funcEntry);  
 }  
 }  
   
 void SemanticAnalyzer::addVariableNodeToSymbolTable(NonTerminalNode \*varDeclNode)  
 {  
 // get the current scope  
 scope \*currScope = \_scopeStack.top();  
   
 // check if the variable already exists in the symbol table (in current or parent scope)  
 TerminalNode \*nameNode = (TerminalNode \*)(varDeclNode->GetChildren()[1]);  
 string name = nameNode->getToken()->val;  
 tableEntry entry = currScope->getEntry(name);  
   
 if (entry.name != "\_undeclared")  
 {  
 \_errorHandler->addError(new semanticError("variable already declared", nameNode->getToken()));  
 }  
 else  
 {  
 // add variable to the symbol table  
 currScope->addTableEntry(createTableEntery\_varDec(varDeclNode));  
 }  
 }  
   
 void SemanticAnalyzer::addParamNodeToSymbolTable(NonTerminalNode \*paramNode)  
 {  
 // get the current scope  
 scope \*currScope = \_scopeStack.top();  
   
 // check if the variable already exists in the symbol table (in current or parent scope)  
 TerminalNode \*nameNode = (TerminalNode \*)(paramNode->GetChildren()[1]);  
 string name = nameNode->getToken()->val;  
 tableEntry entry = currScope->getEntry(name);  
   
 if (entry.name != "\_undeclared")  
 {  
 \_errorHandler->addError(new semanticError("variable already declared", nameNode->getToken()));  
 }  
 else  
 {  
 // add variable to the symbol table  
 currScope->addTableEntry(createTableEntery\_param(paramNode));  
 }  
 }  
   
 void SemanticAnalyzer::addParamListToSymbolTable(vector<NonTerminalNode \*> paramNodes)  
 {  
 // get the current scope  
 scope \*currScope = \_scopeStack.top();  
 currScope->printScope();  
   
 for (int i = 0; i < paramNodes.size(); i++)  
 {  
 addParamNodeToSymbolTable(paramNodes[i]);  
 }  
 }  
   
 void SemanticAnalyzer::updateScope(SyntaxToken \*currToken)  
 {  
 if (currToken->kind == SyntaxKind::OPEN\_CURLY)  
 {  
 // entering scope  
 scope \*newScope = new scope();  
   
 bool isFunctionScope = true;  
   
 // if the stack is empty it means its a new function  
 // so just connect it to the stack knowing it dosent have a parent  
 // later wre connect the function to the scope in the updateSymbolTable() func  
   
 if (!\_scopeStack.empty())  
 {  
 scope \*oldScope = \_scopeStack.top();  
 oldScope->addInnerScope(newScope);  
 newScope->setParentScope(oldScope);  
 isFunctionScope = false;  
 }  
   
 \_scopeStack.push(newScope);  
   
 if (isFunctionScope)  
 {  
 addParamListToSymbolTable(\_currFunctionParamNodes);  
 \_currFunctionParamNodes.clear(); // clear the param nodes after adding them to the symbol table  
 }  
 }  
 else if (currToken->kind == SyntaxKind::CLOSED\_CURLY)  
 {  
 // exiting scope  
 scope \*currScope = \_scopeStack.top();  
 \_scopeStack.pop();  
   
 if (\_scopeStack.empty())  
 \_currRootScope = currScope; // if the stack is empty it means we are at the end of the function  
 }  
 }  
   
 void SemanticAnalyzer::updateSybolTable(ASTNode \*node)  
 {  
 if (node->GetType() == NON\_TERMINAL)  
 {  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)node;  
 if (ntNode->getNonTerminalKind() == FUNCTION\_DECL)  
 {  
 addFunctionNodeToSymbolTable(ntNode);  
 }  
   
 else if (ntNode->getNonTerminalKind() == VAR\_DECL\_EXPR)  
 {  
 addVariableNodeToSymbolTable(ntNode);  
 }  
   
 else if (ntNode->getNonTerminalKind() == PARAM\_LIST)  
 {  
 \_currFunctionParamNodes = getFunctionParamNodes(ntNode);  
 }  
   
 else if (isReturnStatement(node))  
 {  
 \_currFunctionReturnNodes.push\_back((NonTerminalNode \*)node);  
 }  
 }  
 }  
   
 void SemanticAnalyzer::assignNodeType(ASTNode \*node)  
 {  
 if (node->GetType() == NON\_TERMINAL)  
 {  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)node;  
 NonTerminal ntKind = ntNode->getNonTerminalKind();  
   
 if (\_nonTerminalAssignActions.find(ntKind) != \_nonTerminalAssignActions.end())  
 {  
 (this->\*\_nonTerminalAssignActions[ntKind])(node);  
 }  
 }  
 else if (node->GetType() == TERMINAL)  
 {  
 TerminalNode \*tNode = (TerminalNode \*)node;  
 SyntaxKind kind = tNode->getToken()->kind;  
   
 if (assignTerminal.find(kind) != assignTerminal.end())  
 {  
 node->SetValType(valType{assignTerminal[kind], 0, false, false});  
 }  
 }  
 }  
   
 bool areTypesEqual(valType a, valType b)  
 {  
 return a.type == b.type &&  
 a.isPointer == b.isPointer &&  
 a.isArray == b.isArray;  
 }  
   
 valType checkArithmeticCompatibility(valType left, valType right, SyntaxToken \*opToken, ErrorHandler \*\_errorHandler)  
 {  
 valType res = {UNDIFINED, 0, false, false};  
 bool errorOccurred = false;  
   
 if (left.isPointer || right.isPointer)  
 {  
 if ((opToken->kind == PLUS || opToken->kind == MINUS) &&  
 ((left.isPointer && right.isPointer)))  
 {  
 res = left.isPointer ? left : right;  
 }  
 else  
 {  
 \_errorHandler->addError(new semanticError("pointer arithmetic not allowed", opToken));  
 errorOccurred = true;  
 }  
 }  
 else if (left.isArray || right.isArray)  
 {  
 \_errorHandler->addError(new semanticError("array arithmetic not allowed", opToken));  
 errorOccurred = true;  
 }  
 else if (left.type == FLOAT || right.type == FLOAT)  
 {  
 res = {FLOAT, 0, false, false};  
 }  
 else if (left.type == INT || right.type == INT)  
 {  
 res = {INT, 0, false, false};  
 }  
 else if (left.type == CHAR || right.type == CHAR)  
 {  
 res = {INT, 0, false, false};  
 }  
 else  
 {  
 \_errorHandler->addError(new semanticError("incompatible types for arithmetic", opToken));  
 errorOccurred = true;  
 }  
   
 if (errorOccurred)  
 res = {UNDIFINED, 0, false, false};  
   
 return res;  
 }  
   
 valType checkComparisonCompatibility(valType left, valType right, SyntaxToken \*opToken, ErrorHandler \*\_errorHandler)  
 {  
 valType res = {INT, 0, false, false};  
 if (!areTypesEqual(left, right))  
 {  
 \_errorHandler->addError(new semanticError("incompatible types for comparison", opToken));  
 res = {UNDIFINED, 0, false, false};  
 }  
 return res;  
 }  
   
 valType checkLogicalCompatibility(valType left, valType right, SyntaxToken \*opToken, ErrorHandler \*\_errorHandler)  
 {  
 valType res = {INT, 0, false, false};  
 if (left.type != INT || right.type != INT)  
 {  
 \_errorHandler->addError(new semanticError("logical operators require int operands", opToken));  
 res = {UNDIFINED, 0, false, false};  
 }  
 return res;  
 }  
   
 valType checkBitwiseCompatibility(valType left, valType right, SyntaxToken \*opToken, ErrorHandler \*\_errorHandler)  
 {  
 valType res = {INT, 0, false, false};  
 if ((left.type != INT && left.type != CHAR) || (right.type != INT && right.type != CHAR))  
 {  
 \_errorHandler->addError(new semanticError("bitwise operators require int or char operands", opToken));  
 res = {UNDIFINED, 0, false, false};  
 }  
 return res;  
 }  
   
 valType SemanticAnalyzer::checkCompatibilityBinaryOp(valType leftOp, valType rightOp, SyntaxToken \*opToken)  
 {  
 valType res = {UNDIFINED, 0, false, false};  
   
 if (opToken->kind == PLUS || opToken->kind == MINUS || opToken->kind == STAR || opToken->kind == SLASH || opToken->kind == COMMA)  
 {  
 res = checkArithmeticCompatibility(leftOp, rightOp, opToken, \_errorHandler);  
 }  
 else if (opToken->kind == EQUALS\_EQUALS || opToken->kind == BANG\_EQUALS ||  
 opToken->kind == LESS\_THAN || opToken->kind == GREATER\_THAN ||  
 opToken->kind == LESS\_THAN\_EQUALS || opToken->kind == GREATER\_THAN\_EQUALS)  
 {  
 res = checkComparisonCompatibility(leftOp, rightOp, opToken, \_errorHandler);  
 }  
 else if (opToken->kind == PIPE\_PIPE || opToken->kind == AMPERSAND\_AMPERSAND)  
 {  
 res = checkLogicalCompatibility(leftOp, rightOp, opToken, \_errorHandler);  
 }  
 else if (opToken->kind == PIPE || opToken->kind == AMPERSAND || opToken->kind == CARET)  
 {  
 res = checkBitwiseCompatibility(leftOp, rightOp, opToken, \_errorHandler);  
 }  
   
 return res;  
 }  
   
 bool isWideningCompatible(baseType target, baseType source)  
 {  
 if (target == FLOAT)  
 return source == FLOAT || source == INT || source == CHAR;  
 if (target == INT)  
 return source == INT || source == CHAR;  
 if (target == CHAR)  
 return source == CHAR;  
 return false;  
 }  
   
 valType SemanticAnalyzer::checkCompatibilityAssignExp(valType leftOp, valType rightOp, SyntaxToken \*opToken)  
 {  
 bool errorOccurred = false;  
 valType res = leftOp;  
   
 if (isPointerToPointerAssignInvalid(leftOp, rightOp, opToken))  
 {  
 errorOccurred = true;  
 }  
 else if (isArrayToPointerAssignAllowed(leftOp, rightOp))  
 {  
 // valid ??? do nothing, res is already correct  
 }  
 else if (isArrayAssignmentInvalid(leftOp, rightOp, opToken))  
 {  
 errorOccurred = true;  
 }  
 else if (isPointerMismatch(leftOp, rightOp, opToken))  
 {  
 errorOccurred = true;  
 }  
 else if (!isWideningCompatible(leftOp.type, rightOp.type))  
 {  
 \_errorHandler->addError(new semanticError("incompatible types for assignment", opToken));  
 errorOccurred = true;  
 }  
   
 if (errorOccurred)  
 {  
 res = {UNDIFINED, 0, false, false};  
 }  
   
 return res;  
 }  
   
 bool SemanticAnalyzer::isPointerToPointerAssignInvalid(valType left, valType right, SyntaxToken \*token)  
 {  
 if (left.isPointer && right.isPointer && left.type != right.type)  
 {  
 \_errorHandler->addError(new semanticError("incompatible pointer types for assignment", token));  
 return true;  
 }  
 return false;  
 }  
   
 bool SemanticAnalyzer::isArrayToPointerAssignAllowed(valType left, valType right)  
 {  
 return left.isPointer && right.isArray && left.type == right.type;  
 }  
   
 bool SemanticAnalyzer::isArrayAssignmentInvalid(valType left, valType right, SyntaxToken \*token)  
 {  
 if (left.isArray && right.isArray)  
 {  
 if (left.size != right.size)  
 {  
 \_errorHandler->addError(new semanticError("array size mismatch", token));  
 return true;  
 }  
 if (!isWideningCompatible(left.type, right.type))  
 {  
 \_errorHandler->addError(new semanticError("incompatible array types for assignment", token));  
 return true;  
 }  
 return false; // valid array-to-array  
 }  
 if (left.isArray && !right.isArray)  
 {  
 \_errorHandler->addError(new semanticError("cannot assign non-array value to array", token));  
 return true;  
 }  
 if (!left.isArray && right.isArray)  
 {  
 \_errorHandler->addError(new semanticError("cannot assign array to non-array", token));  
 return true;  
 }  
 return false;  
 }  
   
 bool SemanticAnalyzer::isPointerMismatch(valType left, valType right, SyntaxToken \*token)  
 {  
 if (!left.isPointer && right.isPointer)  
 {  
 \_errorHandler->addError(new semanticError("cannot assign pointer to non-pointer", token));  
 return true;  
 }  
 if (left.isPointer && !right.isPointer)  
 {  
 \_errorHandler->addError(new semanticError("cannot assign non-pointer to pointer", token));  
 return true;  
 }  
 return false;  
 }  
   
 void SemanticAnalyzer::checkReturnStatements(functionEntry \*funcEntry)  
 {  
 // check if the function has a return statement  
 vector<NonTerminalNode \*> returnNodes = \_currFunctionReturnNodes;  
 valType returnType = funcEntry->getReturnType();  
   
 for (int i = 0; i < returnNodes.size(); i++)  
 {  
 NonTerminalNode \*returnNode = returnNodes[i];  
   
 valType nodeType = returnNode->GetValType();  
   
 if (nodeType.type != returnType.type || nodeType.isPointer != returnType.isPointer || nodeType.isArray != returnType.isArray)  
 {  
 \_errorHandler->addError(new semanticError("return type does not match function declaration"));  
 }  
 }  
   
 \_currFunctionReturnNodes.clear();  
 }  
   
 valType SemanticAnalyzer::getVarType(SyntaxToken \*IDToken)  
 {  
 // get the current scope  
 scope \*currScope = \_scopeStack.top();  
   
 // check if the variable already exists in the symbol table (in current or parent scope)  
 string name = IDToken->val;  
 tableEntry entry = currScope->getEntry(name);  
   
 valType res = {UNDIFINED, 0, false, false};  
   
 if (entry.name == "\_undeclared")  
 {  
 \_errorHandler->addError(new semanticError("variable not declared", IDToken));  
 }  
 else  
 {  
 res = entry.type;  
 }  
   
 return res;  
 }  
   
 // returns the functions return type and checks if the function call parameters match the function declaration parameters  
 // if the function is not declared it will add an error to the error handler  
 // if the function call parameters do not match the function declaration parameters it will add an error to the error handler  
 valType SemanticAnalyzer::getFunctionCallValTypeAndCheck(NonTerminalNode \*funcCallNode)  
 {  
 valType res = {UNDIFINED, 1, false, false};  
 // get the function name  
 TerminalNode \*nameNode = (TerminalNode \*)(funcCallNode->GetChildren()[0]);  
 string name = nameNode->getToken()->val;  
   
 // check if the function call parameters match the function declaration parameters  
 vector<ASTNode \*> children = funcCallNode->GetChildren();  
   
 NonTerminalNode \*exprList = (NonTerminalNode \*)(children[2]);  
 vector<ASTNode \*> paramListChildren = exprList->GetChildren();  
   
 vector<NonTerminalNode \*> paramNodes = getFunctionCallArgsNodes(exprList);  
 functionEntry \*entry = \_symbolTable->getFunction(name);  
   
 bool match = true;  
   
 if (entry == nullptr)  
 {  
 \_errorHandler->addError(new semanticError("function not declared", nameNode->getToken()));  
 }  
 else  
 {  
 res = entry->getReturnType();  
 vector<valType> paramTypes = entry->getParamTypes();  
 if (paramNodes.size() != paramTypes.size())  
 {  
 match = false;  
 }  
 else  
 {  
 for (int i = 0; i < paramNodes.size(); i++)  
 {  
 valType paramType = paramNodes[i]->GetValType();  
 valType expectedType = paramTypes[i];  
   
 if (paramType.type != expectedType.type || paramType.isPointer != expectedType.isPointer || paramType.isArray != expectedType.isArray)  
 {  
 match = false;  
 }  
 }  
 }  
 }  
   
 if (!match)  
 {  
 \_errorHandler->addError(new semanticError("function call parameters do not match", nameNode->getToken()));  
 }  
   
 return res;  
 }  
   
 void SemanticAnalyzer::initAssignActions()  
 {  
 \_nonTerminalAssignActions[PARAM] = &SemanticAnalyzer::assignParamNodeType;  
 \_nonTerminalAssignActions[TYPE] = &SemanticAnalyzer::assignTypeNodeType;  
 \_nonTerminalAssignActions[BASE\_TYPE] = &SemanticAnalyzer::assignBaseTypeNodeType;  
 \_nonTerminalAssignActions[VAR\_DECL\_EXPR] = &SemanticAnalyzer::assignVarDeclExprNodeType;  
 \_nonTerminalAssignActions[ASSIGN\_VALUE] = &SemanticAnalyzer::assignAssignValueNodeType;  
 \_nonTerminalAssignActions[ASSIGN\_EXPR] = &SemanticAnalyzer::assignAssignExprNodeType;  
 \_nonTerminalAssignActions[ASSIGN\_TARGET] = &SemanticAnalyzer::assignAssignTargetNodeType;  
 \_nonTerminalAssignActions[CONDITION\_OP] = &SemanticAnalyzer::assignConditionOpNodeType;  
 \_nonTerminalAssignActions[SIMPLE\_STMT] = &SemanticAnalyzer::assignSimpleStmtNodeType;  
 \_nonTerminalAssignActions[EXPR\_LIST] = &SemanticAnalyzer::assignExprListNodeType;  
 \_nonTerminalAssignActions[EXPR\_LIST\_NON\_EMPTY] = &SemanticAnalyzer::assignExprListNonEmptyNodeType;  
 \_nonTerminalAssignActions[EXPR] = &SemanticAnalyzer::assignExprNodeType;  
 \_nonTerminalAssignActions[LOGICAL\_EXPR] = &SemanticAnalyzer::assignLogicalExprNodeType;  
 \_nonTerminalAssignActions[RELATIONAL\_EXPR] = &SemanticAnalyzer::assignRelationalExprNodeType;  
 \_nonTerminalAssignActions[ADD\_EXPR] = &SemanticAnalyzer::assignAddExprNodeType;  
 \_nonTerminalAssignActions[MUL\_EXPR] = &SemanticAnalyzer::assignMulExprNodeType;  
 \_nonTerminalAssignActions[UNARY\_EXPR] = &SemanticAnalyzer::assignUnaryExprNodeType;  
 \_nonTerminalAssignActions[INCREMENT\_EXPR] = &SemanticAnalyzer::assignIncrementExprNodeType;  
 \_nonTerminalAssignActions[ADDRESS\_EXPR] = &SemanticAnalyzer::assignAddressExprNodeType;  
 \_nonTerminalAssignActions[DEREFERENCE\_EXPR] = &SemanticAnalyzer::assignDereferenceExprNodeType;  
 \_nonTerminalAssignActions[PRIMARY\_EXPR] = &SemanticAnalyzer::assignPrimaryExprNodeType;  
 }  
   
 void SemanticAnalyzer::assignParamNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignTypeNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 valType baseType = children[0]->GetValType();  
 if (children.size() == 1)  
 {  
 resType = baseType;  
 }  
 else if (children.size() == 2)  
 {  
 resType = {baseType.type, baseType.size, true, false};  
 }  
 else if (children.size() == 4)  
 {  
 TerminalNode \*sizeNode = ((TerminalNode \*)(children[2]));  
 int size = atoi(sizeNode->getToken()->val.c\_str());  
   
 resType = {baseType.type, size, false, true};  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignBaseTypeNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignVarDeclExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 TerminalNode \*varNode = (TerminalNode \*)(ntNode->GetChildren()[1]);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 valType leftOpVarType = children[0]->GetValType();  
   
 NonTerminalNode \*initOptNode = (NonTerminalNode \*)(children[2]);  
 vector<ASTNode \*> initOptChildren = initOptNode->GetChildren();  
   
 if (initOptChildren.size() > 0)  
 {  
 TerminalNode \*assignOpNode = (TerminalNode \*)(initOptChildren[0]);  
 SyntaxToken \*opToken = assignOpNode->getToken();  
   
 NonTerminalNode \*assignValueNode = (NonTerminalNode \*)(initOptChildren[1]);  
 valType rightOpVarType = assignValueNode->GetValType();  
   
 resType = checkCompatibilityAssignExp(leftOpVarType, rightOpVarType, assignOpNode->getToken());  
 node->SetValType(resType);  
 }  
 }  
   
 void SemanticAnalyzer::assignAssignValueNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
   
 else if (children.size() == 3)  
 {  
 valType type = children[1]->GetValType();  
 resType = {type.type, type.size, type.isPointer, true};  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignAssignExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() >= 3)  
 {  
 valType leftOp = children[0]->GetValType();  
 valType rightOp = children[2]->GetValType();  
   
 NonTerminalNode \*assignOpNode = (NonTerminalNode \*)(children[1]);  
 SyntaxToken \*opToken = ((TerminalNode \*)(assignOpNode->GetChildren()[0]))->getToken();  
   
 resType = checkCompatibilityAssignExp(leftOp, rightOp, opToken);  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignAssignTargetNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 TerminalNode \*varNode = (TerminalNode \*)(children[0]);  
 resType = getVarType(varNode->getToken());  
 }  
 else if (children.size() == 4)  
 {  
 valType arrType = children[0]->GetValType();  
 if (!arrType.isArray)  
 {  
 \_errorHandler->addError(new semanticError("indexing non-array type", ((TerminalNode \*)(children[1]))->getToken()));  
 }  
 else  
 {  
 resType = {arrType.type, arrType.size, arrType.isPointer, false};  
 }  
 }  
 else if (children.size() == 2)  
 {  
 valType ptrType = \_scopeStack.top()->getEntry(((TerminalNode \*)(children[1]))->getToken()->val).type;  
 if (!ptrType.isPointer)  
 {  
 \_errorHandler->addError(new semanticError("dereferencing non-pointer type", ((TerminalNode \*)(children[0]))->getToken()));  
 }  
 else  
 {  
 resType = {ptrType.type, ptrType.size, false, ptrType.isArray};  
 }  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignConditionOpNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 valType condType = children[0]->GetValType();  
 if (condType.type != INT && !condType.isPointer)  
 {  
 \_errorHandler->addError(new semanticError("condition must be int or pointer", ((TerminalNode \*)(children[0]))->getToken()));  
 }  
 else  
 {  
 resType = condType;  
 }  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignSimpleStmtNodeType(ASTNode \*node)  
 {  
 if (isReturnStatement(node))  
 {  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)node;  
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 NonTerminalNode \*ExptOpt = (NonTerminalNode \*)(children[1]);  
 vector<ASTNode \*> ExptOptChildren = ExptOpt->GetChildren();  
 if (ExptOptChildren.size() > 0)  
 {  
 valType returnType = ExptOptChildren[0]->GetValType();  
 node->SetValType(returnType);  
 }  
 }  
   
 if(isFuncCall(node))  
 {  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)node;  
   
 valType funcCallType = getFunctionCallValTypeAndCheck(ntNode);  
 node->SetValType(funcCallType);  
 }  
 }  
   
 void SemanticAnalyzer::assignExprListNodeType(ASTNode \*node)  
 {  
 vector<ASTNode \*> children = ((NonTerminalNode \*)(node))->GetChildren();  
 valType resType = {UNDIFINED, 0, false, false};  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignExprListNonEmptyNodeType(ASTNode \*node)  
 {  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 valType resType = children[0]->GetValType();  
 resType.isArray = false;  
 resType.isPointer = false;  
   
 if (children.size() == 3)  
 {  
 int prevSize = resType.size;  
   
 valType rightOp = children[2]->GetValType();  
 rightOp.isArray = false;  
 rightOp.isPointer = false;  
   
 SyntaxToken \*opToken = ((TerminalNode \*)(children[1]))->getToken();  
 resType = checkCompatibilityBinaryOp(resType, rightOp, opToken);  
   
 resType = valType{resType.type, prevSize + 1, resType.isPointer, resType.isArray};  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignLogicalExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
 else if (children.size() == 3)  
 {  
 valType leftOp = children[0]->GetValType();  
 valType rightOp = children[2]->GetValType();  
 SyntaxToken \*opToken = ((TerminalNode \*)(children[1]))->getToken();  
 resType = checkCompatibilityBinaryOp(leftOp, rightOp, opToken);  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignRelationalExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
 else if (children.size() == 3)  
 {  
 valType leftOp = children[0]->GetValType();  
 valType rightOp = children[2]->GetValType();  
 SyntaxToken \*opToken = ((TerminalNode \*)(children[1]))->getToken();  
 resType = checkCompatibilityBinaryOp(leftOp, rightOp, opToken);  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignAddExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
 else if (children.size() == 3)  
 {  
 valType leftOp = children[0]->GetValType();  
 valType rightOp = children[2]->GetValType();  
 SyntaxToken \*opToken = ((TerminalNode \*)(children[1]))->getToken();  
 resType = checkCompatibilityBinaryOp(leftOp, rightOp, opToken);  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignMulExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
 else if (children.size() == 3)  
 {  
 valType leftOp = children[0]->GetValType();  
 valType rightOp = children[2]->GetValType();  
 SyntaxToken \*opToken = ((TerminalNode \*)(children[1]))->getToken();  
 resType = checkCompatibilityBinaryOp(leftOp, rightOp, opToken);  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignUnaryExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 1)  
 {  
 resType = children[0]->GetValType();  
 }  
 else if (children.size() == 2)  
 {  
 valType operandType = children[1]->GetValType();  
 SyntaxToken \*opToken = ((TerminalNode \*)(children[0]))->getToken();  
   
 if (operandType.isPointer || operandType.isArray)  
 {  
 \_errorHandler->addError(new semanticError("unary operator not allowed on pointer/array", opToken));  
 }  
 else  
 {  
 resType = operandType;  
 }  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignIncrementExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
   
 TerminalNode \*firstChild = (TerminalNode \*)(children[0]);  
 TerminalNode \*secondChild = (TerminalNode \*)(children[1]);  
   
 TerminalNode \*varNode = firstChild->getToken()->kind == IDENTIFIER ? firstChild : secondChild;  
 valType operandType = getVarType(varNode->getToken());  
   
 if (operandType.type != INT && !operandType.isPointer)  
 {  
 \_errorHandler->addError(new semanticError("increment/decrement requires int or pointer", varNode->getToken()));  
 }  
 else  
 {  
 resType = operandType;  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignAddressExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 2)  
 {  
 valType varType = getVarType(((TerminalNode \*)(children[1]))->getToken());  
   
 if (varType.isPointer || varType.isArray)  
 {  
 \_errorHandler->addError(new semanticError("double pointer abstraction is not allowed!", ((TerminalNode \*)(children[0]))->getToken()));  
 }  
   
 resType = {varType.type, varType.size, true, varType.isArray};  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignDereferenceExprNodeType(ASTNode \*node)  
 {  
 valType resType = {UNDIFINED, 0, false, false};  
 NonTerminalNode \*ntNode = (NonTerminalNode \*)(node);  
   
 vector<ASTNode \*> children = ntNode->GetChildren();  
 if (children.size() == 2)  
 {  
 valType varType = \_scopeStack.top()->getEntry(((TerminalNode \*)(children[1]))->getToken()->val).type;  
 if (!varType.isPointer)  
 {  
 \_errorHandler->addError(new semanticError("dereferencing non-pointer type", ((TerminalNode \*)(children[0]))->getToken()));  
 }  
 else  
 {  
 resType = {varType.type, varType.size, false, varType.isArray};  
 }  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::assignPrimaryExprNodeType(ASTNode \*node)  
 {  
 valType resType{UNDIFINED, 0, false, false};  
 auto \*ntNode = static\_cast<NonTerminalNode \*>(node);  
 auto children = ntNode->GetChildren();  
   
 if (children.size() == 1)  
 {  
 ASTNode \*child = children[0];  
 if (child->GetType() == NON\_TERMINAL)  
 {  
 // Propagate result of DereferenceExpr or IncrementExpr  
 resType = child->GetValType();  
 }  
 else  
 {  
 TerminalNode \*tNode = (TerminalNode \*)(child);  
 if (tNode->getToken()->kind == IDENTIFIER)  
 resType = getVarType(tNode->getToken());  
 else  
 resType = {assignTerminal[tNode->getToken()->kind], 0, false, false};  
 }  
 }  
 else if (children.size() == 3)  
 {  
 // Parenthesized: '(' Expr ')'  
 resType = children[1]->GetValType();  
 }  
 else if (isArrDeref(node))  
 {  
 // Array indexing  
 string varName = static\_cast<TerminalNode \*>(children[0])->getToken()->val;  
 valType type = \_scopeStack.top()->getEntry(varName).type;  
 if (!type.isArray && !type.isPointer)  
 \_errorHandler->addError(new semanticError("indexing non-array type", static\_cast<TerminalNode \*>(children[1])->getToken()));  
 else  
 resType = {type.type, type.size, false, false};  
 }  
 else if (isFuncCall(node))  
 {  
 // Function call  
 resType = getFunctionCallValTypeAndCheck(ntNode);  
 }  
   
 node->SetValType(resType);  
 }  
   
 void SemanticAnalyzer::checkForMainFunction()  
 {  
 // check if the main function is declared  
 functionEntry \*mainFunc = \_symbolTable->getFunction("main");  
 if (mainFunc == nullptr)  
 {  
 \_errorHandler->addError(new semanticError("main function not declared"));  
 }  
 else if (mainFunc->getReturnType().type != INT)  
 {  
 cout << "main function return type: " << mainFunc->getReturnType().type << endl;  
 // check if the main function has a return type of int  
 \_errorHandler->addError(new semanticError("main function must return int"));  
 }  
 }

## semantic.hpp

#ifndef \_\_SEMANTIC\_ANALYZER  
 #define \_\_SEMANTIC\_ANALYZER  
   
 #include "../nodes/nodes.hpp"  
 #include "../nodes/nodeAnalyzer/nodeAnalyzer.hpp"  
 #include "../symbolTable/scope/scope.hpp"  
 #include "../symbolTable/tableEntry/tableEntry.hpp"  
 #include "../symbolTable/symbolTable.hpp"  
 #include "../errorHandler/errorHandler.hpp"  
 #include "../errors/errors.hpp"  
 #include <stack>  
   
 extern map<SyntaxKind, baseType> assignTerminal;  
   
 class SemanticAnalyzer  
 {  
 private:  
 ErrorHandler \*\_errorHandler;  
 SymbolTable \*\_symbolTable;  
 std::stack<scope \*> \_scopeStack;  
 scope \*\_currRootScope;  
 std::vector<NonTerminalNode \*> \_currFunctionParamNodes;  
 std::vector<NonTerminalNode \*> \_currFunctionReturnNodes;  
 std::map<NonTerminal, void (SemanticAnalyzer::\*)(ASTNode \*)> \_nonTerminalAssignActions;  
   
 // Refactored helper functions  
 bool isPointerToPointerAssignInvalid(valType left, valType right, SyntaxToken \*token);  
 bool isArrayToPointerAssignAllowed(valType left, valType right);  
 bool isArrayAssignmentInvalid(valType left, valType right, SyntaxToken \*token);  
 bool isPointerMismatch(valType left, valType right, SyntaxToken \*token);  
   
 // Assignment type inference helpers  
 void initAssignActions();  
 valType getVarType(SyntaxToken \*IDToken);  
 valType getFunctionCallValTypeAndCheck(NonTerminalNode \*funcCallNode);  
   
   
 // Type assignment  
 void assignParamNodeType(ASTNode \*node);  
 void assignTypeNodeType(ASTNode \*node);  
 void assignBaseTypeNodeType(ASTNode \*node);  
 void assignVarDeclExprNodeType(ASTNode \*node);  
 void assignAssignValueNodeType(ASTNode \*node);  
 void assignAssignExprNodeType(ASTNode \*node);  
 void assignAssignTargetNodeType(ASTNode \*node);  
 void assignConditionOpNodeType(ASTNode \*node);  
 void assignSimpleStmtNodeType(ASTNode \*node);  
 void assignExprListNodeType(ASTNode \*node);  
 void assignExprListNonEmptyNodeType(ASTNode \*node);  
 void assignExprNodeType(ASTNode \*node);  
 void assignLogicalExprNodeType(ASTNode \*node);  
 void assignRelationalExprNodeType(ASTNode \*node);  
 void assignAddExprNodeType(ASTNode \*node);  
 void assignMulExprNodeType(ASTNode \*node);  
 void assignUnaryExprNodeType(ASTNode \*node);  
 void assignIncrementExprNodeType(ASTNode \*node);  
 void assignAddressExprNodeType(ASTNode \*node);  
 void assignDereferenceExprNodeType(ASTNode \*node);  
 void assignPrimaryExprNodeType(ASTNode \*node);  
   
 public:  
 SemanticAnalyzer(ErrorHandler \*errorHandler, SymbolTable \*symbolTable);  
   
 void updateSybolTable(ASTNode \*node);  
 void updateScope(SyntaxToken \*currToken);  
 void addFunctionNodeToSymbolTable(NonTerminalNode \*funcDeclNode);  
 void addVariableNodeToSymbolTable(NonTerminalNode \*varDeclNode);  
 void addParamNodeToSymbolTable(NonTerminalNode \*paramNode);  
 void addParamListToSymbolTable(std::vector<NonTerminalNode \*> paramNodes);  
 void assignNodeType(ASTNode \*node);  
   
 valType checkCompatibilityBinaryOp(valType leftOp, valType rightOp, SyntaxToken \*opToken);  
 valType checkCompatibilityAssignExp(valType leftOp, valType rightOp, SyntaxToken \*opToken);  
   
 void checkReturnStatements(functionEntry \*funcEntry);  
 void checkForMainFunction();  
 };  
   
 #endif // SEMANTIC\_HPP

## functionEntry.cpp

#include "functionEntry.hpp"  
 #include <iostream>  
 #include <string>  
 #include <vector>  
   
 void functionEntry::print() const  
 {  
 cout << "Function Name: " << \_name << endl;  
 cout << "Return Type: " << valTypeToString(\_returnType) << endl;  
 cout << "Parameter Types: " << endl;  
 cout << "num of parameters: " << \_paramTypes.size() << endl;  
 for (const auto &paramType : \_paramTypes)  
 {  
 cout << valTypeToString(paramType) << " ";  
 }  
   
 if(\_scopeRoot) \_scopeRoot->printScope();  
   
 cout << "End of Function" << endl;  
 cout << "----------------------------------------" << endl;  
 cout << endl;  
 }

## functionEntry.hpp

#ifndef \_\_FUNCTION\_ENTRY  
 #define \_\_FUNCTION\_ENTRY  
   
 #include "../../token/token.hpp"  
 #include "../scope/scope.hpp"  
 #include <String>  
 #include <vector>  
   
 class functionEntry  
 {  
 private:  
 string \_name;  
 valType \_returnType;  
 vector<valType> \_paramTypes;  
   
 scope \*\_scopeRoot;  
   
 public:  
 functionEntry(string name, valType returnType, vector<valType> paramTypes) : \_name(name), \_returnType(returnType), \_paramTypes(paramTypes)   
 {\_scopeRoot = nullptr;}  
   
 string getName() const { return \_name; }  
 valType getReturnType() const { return \_returnType; }  
 vector<valType> getParamTypes() const { return \_paramTypes; }  
   
 scope \*getInnerScope() const { return \_scopeRoot; }  
   
 void setInnerScope(scope \*innerScope) { \_scopeRoot = innerScope; }  
 void print() const;  
 };  
   
 #endif

## scope.cpp

## scope.hpp

#ifndef SCOPE  
 #define SCOPE  
   
 #include "..\tableEntry\tableEntry.hpp"  
   
 #include <string>  
 #include <vector>  
 #include <iostream>  
   
 using namespace std;  
   
 class scope  
 {  
 private:  
 vector<tableEntry> \_tableEntries;  
 vector<scope \*> \_innerScopes;  
 scope \*\_parentScope = nullptr;  
   
 public:  
 scope() {}  
   
 void addTableEntry(tableEntry entry)  
 {  
 \_tableEntries.push\_back(entry);  
 }  
   
 void addInnerScope(scope \*innerScope) { \_innerScopes.push\_back(innerScope); }  
 void setParentScope(scope \*parentScope) { \_parentScope = parentScope; }  
 scope \*getParentScope() const { return \_parentScope; }  
   
 vector<tableEntry> &getEntries() { return \_tableEntries; }  
   
 // returns the entery with the requested name  
 // if the name is not found in this scope, it will search in the inner scopes  
 tableEntry getEntry(string name)  
 {  
 tableEntry res = {"\_undeclared", {}};  
   
 for (tableEntry entry : \_tableEntries)  
 {  
 if (entry.name == name)  
 {  
 res = entry;  
 }  
 }  
   
 if (res.name == "\_undeclared" && \_parentScope != nullptr)  
 {  
 res = \_parentScope->getEntry(name);  
 }  
   
 return res;  
 }  
 vector<scope \*> getInnerScopes() const { return \_innerScopes; }  
   
 // returns the entery with the requested name  
 tableEntry getInnerScopeEntrie(string name)  
 {  
 tableEntry res = {"\_undeclared", {}};  
 for (tableEntry entry : \_tableEntries)  
 {  
 if (entry.name == name)  
 {  
 res = entry;  
 }  
 }  
 return res;  
 }  
   
 void printScope()  
 {  
   
 for (auto &entry : \_tableEntries)  
 {  
 // Make sure printTableEntery handles nullptrs or malformed data  
 printTableEntery(&entry);  
 }  
   
 for (auto \*innerScope : \_innerScopes)  
 {  
 if (innerScope != nullptr) // <-- this is the fix  
 {  
 innerScope->printScope();  
 }  
 else  
 {  
 cout << "Warning: nullptr inner scope found!" << endl;  
 }  
 }  
   
 }  
 };  
   
 #endif

## symbolTable.cpp

#include "actionTable.hpp"  
 #include "tableEntry/tableEntry.hpp"  
 #include "functionEntry/functionEntry.hpp"  
 #include "symbolTable.hpp"  
 #include "../parser/grammerSymbol/grammerSymbol.hpp"  
 #include "../semantic/semantic.hpp"  
 #include "../token/token.hpp"  
 #include "../nodes/nodes.hpp"  
 #include <map>  
 #include <vector>  
 #include <String>  
 #include <algorithm>  
   
 // returns the entry with the requested name  
 // if function not found returns nullptr  
 functionEntry \*SymbolTable::getFunction(string name)  
 {  
 functionEntry \*res = nullptr;  
 vector<functionEntry \*> enteries = getFunctions();  
   
 for (functionEntry \*entry : enteries)  
 {  
 if (entry->getName() == name)  
 {  
 res = entry;  
 }  
 }  
   
 return res;  
 }  
   
 valType createVarDeclExprType(NonTerminalNode \*typeNode)  
 {  
 vector<ASTNode \*> children = typeNode->GetChildren();  
   
 NonTerminalNode \*baseTypeNode = (NonTerminalNode \*)children[0];  
 SyntaxKind type = ((TerminalNode \*)baseTypeNode->GetChildren()[0])->getToken()->kind;  
   
 int size = 1;  
 bool isPointer = false;  
 bool isArray = false;  
   
 // pointer  
 if (children.size() == 2)  
 {  
 isPointer = true;  
 }  
   
 // array  
 if (children.size() == 4)  
 {  
 isArray = true;  
   
 TerminalNode \*sizeNode = (TerminalNode \*)children[2];  
 size = stoi(sizeNode->getToken()->val);  
 }  
   
 valType res = {assignTerminal[type], size, isPointer, isArray};  
 return res;  
 }  
   
 tableEntry createTableEntery\_varDec(NonTerminalNode \*varDecNode)  
 {  
 tableEntry res = tableEntry{"", valType{UNDIFINED, 1, false, false}, false};  
 vector<ASTNode \*> children = varDecNode->GetChildren();  
   
 // set name  
 res.name = ((TerminalNode \*)children[1])->getToken()->val;  
   
 // set type  
 res.type = createVarDeclExprType((NonTerminalNode \*)children[0]);  
   
 return res;  
 }  
   
 tableEntry createTableEntery\_param(NonTerminalNode \*paramNode)  
 {  
 tableEntry res = tableEntry{"", valType{UNDIFINED, 1, false, false}, false};  
 vector<ASTNode \*> children = paramNode->GetChildren();  
   
 // set name  
 res.name = ((TerminalNode \*)children[1])->getToken()->val;  
   
 // set type  
 res.type = createVarDeclExprType((NonTerminalNode \*)children[0]);  
   
 return res;  
 }  
   
 void createFunctionParamTypesHelper(NonTerminalNode \*paramListNonEmptyNode, vector<valType> \*paramTypes)  
 {  
 vector<ASTNode \*> childern = paramListNonEmptyNode->GetChildren();  
 int numOfChildren = childern.size();  
 NonTerminalNode \*typeNode;  
 if (numOfChildren == 1)  
 {  
 typeNode = ((NonTerminalNode \*)(childern[0]->GetChildren()[0]));  
   
 paramTypes->push\_back(createVarDeclExprType(typeNode));  
 }  
   
 if (numOfChildren == 3)  
 {  
 typeNode = ((NonTerminalNode \*)(childern[2]->GetChildren()[0]));  
   
 paramTypes->push\_back(createVarDeclExprType(typeNode));  
   
 createFunctionParamTypesHelper((NonTerminalNode \*)childern[0], paramTypes);  
 }  
 }  
   
 vector<valType> createFunctionParamTypes(NonTerminalNode \*paramListNode)  
 {  
 vector<ASTNode \*> childern = paramListNode->GetChildren();  
 vector<valType> res;  
   
 if (childern.size() > 0)  
 {  
 createFunctionParamTypesHelper((NonTerminalNode \*)childern[0], &res);  
 }  
   
 std::reverse(res.begin(), res.end());  
 return res;  
 }  
   
 void createFunctionParamEnteriesHelper(NonTerminalNode \*paramListNonEmptyNode, vector<tableEntry> \*enteries)  
 {  
 vector<ASTNode \*> childern = paramListNonEmptyNode->GetChildren();  
 int numOfChildren = childern.size();  
 NonTerminalNode \*paramNode;  
 if (numOfChildren == 1)  
 {  
 paramNode = ((NonTerminalNode \*)(childern[0]));  
 enteries->push\_back(createTableEntery\_param(paramNode));  
 }  
   
 if (numOfChildren == 3)  
 {  
 paramNode = ((NonTerminalNode \*)(childern[2]));  
 enteries->push\_back(createTableEntery\_param(paramNode));  
 createFunctionParamEnteriesHelper((NonTerminalNode \*)childern[0], enteries);  
 }  
 }  
   
 vector<tableEntry> createFunctionParamEnteries(NonTerminalNode \*paramListNode)  
 {  
 vector<ASTNode \*> childern = paramListNode->GetChildren();  
 vector<tableEntry> res;  
   
 if (childern.size() > 0)  
 {  
 createFunctionParamEnteriesHelper((NonTerminalNode \*)childern[0], &res);  
 }  
   
 std::reverse(res.begin(), res.end());  
 return res;  
 }

## symbolTable.hpp

#ifndef \_\_SYMBOL\_TABLE  
 #define \_\_SYMBOL\_TABLE  
   
 #include "tableEntry/tableEntry.hpp"  
 #include "functionEntry/functionEntry.hpp"  
 #include "../parser/grammerSymbol/grammerSymbol.hpp"  
 #include "../token/token.hpp"  
 #include "../nodes/nodes.hpp"  
 #include <map>  
 #include <vector>  
 #include <String>  
   
 using namespace std;  
   
 class SymbolTable  
 {  
 private:  
 vector<functionEntry \*> \_functions;  
   
 public:  
 SymbolTable() {   
 addFunction(new functionEntry("printInt", {INT}, {valType{INT}}));   
 addFunction(new functionEntry("printFloat", {INT}, {valType{FLOAT}}));  
 }  
   
 void addFunction(functionEntry \*function) { \_functions.push\_back(function); }  
 functionEntry \*getFunction(string name);  
 const std::vector<functionEntry \*> &getFunctions() const { return \_functions; }  
   
 void print() const  
 {  
 cout << "Symbol Table:" << endl;  
 cout << "num of functions: " << \_functions.size() << endl;  
 for (const auto &function : \_functions)  
 {  
 function->print();  
 }  
 cout << "End of Symbol Table" << endl;  
 }  
 };  
   
 valType createVarDeclExprType(NonTerminalNode \*varNode);  
 tableEntry createTableEntery\_varDec(NonTerminalNode \*varDecNode);  
 tableEntry createTableEntery\_param(NonTerminalNode \*varDecNode);  
 vector<valType> createFunctionParamTypes(NonTerminalNode \*paramListNode);  
 void createFunctionParamTypesHelper(NonTerminalNode \*paramListNode, vector<valType> \*paramTypes);  
 vector<tableEntry> createFunctionParamEnteries(NonTerminalNode \*paramListNode);  
 void createFunctionParamEnteriesHelper(NonTerminalNode \*paramListNode, vector<tableEntry> \*paramTypes);  
   
 #endif

## tableEntry.cpp

#include "tableEntry.hpp"  
 #include <iostream>  
 #include <string>  
 #include <sstream>  
   
 string valTypeToString(valType vType)  
 {  
 stringstream res;  
   
 res << "\e[0;35m"  
 << baseTypeToString(vType.type)  
 << "\033[0m";  
 if (vType.isPointer)  
 {  
 res << "\*";  
 }  
 if (vType.isArray)  
 {  
 res << "["  
 << vType.size  
 << "]";  
 }  
   
 return res.str();  
 }  
   
 string baseTypeToString(baseType bType)  
 {  
 switch (bType)  
 {  
 case INT:  
 return "int";  
 case FLOAT:  
 return "float";  
 case CHAR:  
 return "char";  
 case UNDIFINED:  
 return "undefined";  
 default:  
 return "unknown type";  
 }  
 }  
   
 void printValType(valType vtype)  
 {  
 cout << valTypeToString(vtype) << endl;  
 }  
   
 void printTableEntery(tableEntry \*entry)  
 {  
 cout << "---------------------------------" << endl;  
 cout << "Variable Name: " << entry->name << endl;  
 cout << "Variable Type: " << valTypeToString(entry->type) << endl;  
 cout << "---------------------------------" << endl;  
 }

## tableEntry.hpp

#ifndef \_\_TABLE\_ENTERY  
 #define \_\_TABLE\_ENTERY  
   
 #include "../../token/token.hpp"  
   
 using namespace std;  
   
 enum baseType  
 {  
 INT,  
 FLOAT,  
 CHAR,  
 UNDIFINED,  
 };  
   
 struct valType  
 {  
 baseType type = UNDIFINED;  
 int size = 1;  
 bool isPointer = false;  
 bool isArray = false;  
 };  
   
 struct tableEntry  
 {  
 string name;  
 valType type;  
 bool isInitialized = false;  
 int offset = 0; // offset in the stack  
 string addr = "";  
 };  
   
 string valTypeToString(valType vType);  
 string baseTypeToString(baseType bType);  
 void printValType(valType vtype);  
 void printTableEntery(tableEntry \*entry);  
   
 #endif

## token.cpp

#include "token.hpp"  
 #include <sstream>  
 #include <iostream>  
   
 using namespace std;  
   
 string syntaxKindEnumToString[] = {  
 "INTEGER\_LITERAL", "FLOAT\_LITERAL", "CHAR\_LITERAL", "STRING\_LITERAL", "IDENTIFIER", "KEYWORD\_IF", "KEYWORD\_ELSE", "KEYWORD\_WHILE", "KEYWORD\_FOR",  
 "KEYWORD\_FN", "KEYWORD\_RET", "KEYWORD\_INT", "KEYWORD\_FLOAT", "KEYWORD\_CHAR", "EQUALS", "COMMA", "PLUS",   
 "MINUS", "SLASH", "STAR", "AMPERSAND","PIPE", "CARET", "TILDE",   
 "BANG", "SEMICOLON", "LESS\_THAN", "GREATER\_THAN", "OPEN\_PAREN", "CLOSED\_PAREN", "OPEN\_CURLY", "CLOSED\_CURLY", "OPEN\_BRACKET",  
 "CLOSED\_BRACKET", "RIGHT\_ARROW", "PLUS\_PLUS", "MINUS\_MINUS", "PLUS\_EQUALS", "MINUS\_EQUALS", "SLASH\_EQUALS", "STAR\_EQUALS",  
 "AMPERSAND\_EQUALS","PIPE\_EQUALS", "CARET\_EQUALS", "TILDE\_EQUALS", "EQUALS\_EQUALS",  
 "LESS\_THAN\_EQUALS", "GREATER\_THAN\_EQUALS", "AMPERSAND\_AMPERSAND", "PIPE\_PIPE", "BANG\_EQUALS", "END\_OF\_FILE", "UNEXPECTED\_TOKEN"  
 };  
   
   
 string syntaxTokenToString(SyntaxToken token)  
 {  
 stringstream res;  
 string tokenValue = token.val;  
 res << syntaxKindToString(token.kind)  
 << " ";  
   
 if (!tokenValue.empty())  
 {  
 res << "| " << tokenValue;  
 }  
   
 return res.str();  
 }  
   
 string syntaxKindToString(SyntaxKind kind)  
 {  
 stringstream res;  
 res << "\e[0;36m"  
 << syntaxKindEnumToString[kind]  
 << "\e[0m";  
   
 return res.str();  
 }  
   
 void printSyntaxToken(SyntaxToken token)  
 {  
 cout << syntaxTokenToString(token) << endl;  
 }

## token.hpp

#ifndef \_\_TOKEN  
 #define \_\_TOKEN  
   
 #include <string>  
   
 using namespace std;  
   
 enum SyntaxKind  
 {  
 INTEGER\_LITERAL,  
 FLOAT\_LITERAL,  
 CHAR\_LITERAL,  
 STRING\_LITERAL,  
 IDENTIFIER,  
 KEYWORD\_IF,  
 KEYWORD\_ELSE,  
 KEYWORD\_WHILE,  
 KEYWORD\_FOR,  
 KEYWORD\_FN,  
 KEYWORD\_RET,  
 KEYWORD\_INT,  
 KEYWORD\_FLOAT,  
 KEYWORD\_CHAR,  
 EQUALS,  
 COMMA,  
 PLUS,  
 MINUS,  
 SLASH,  
 STAR,  
 AMPERSAND,  
 PIPE,  
 CARET,  
 TILDE,  
 BANG,  
 SEMICOLON,  
 LESS\_THAN,  
 GREATER\_THAN,  
 OPEN\_PAREN,  
 CLOSED\_PAREN,  
 OPEN\_CURLY,  
 CLOSED\_CURLY,  
 OPEN\_BRACKET,  
 CLOSED\_BRACKET,  
 RIGHT\_ARROW,  
 PLUS\_PLUS,  
 MINUS\_MINUS,  
 PLUS\_EQUALS,  
 MINUS\_EQUALS,  
 SLASH\_EQUALS,  
 STAR\_EQUALS,  
 AMPERSAND\_EQUALS,  
 PIPE\_EQUALS,  
 CARET\_EQUALS,  
 TILDE\_EQUALS,  
 EQUALS\_EQUALS,  
 LESS\_THAN\_EQUALS,  
 GREATER\_THAN\_EQUALS,  
 AMPERSAND\_AMPERSAND,  
 PIPE\_PIPE,  
 BANG\_EQUALS,  
 END\_OF\_FILE,  
 UNEXPECTED\_TOKEN,  
 EPSILON,  
 SYNTAX\_KIND\_COUNT  
 };  
   
 struct SyntaxToken  
 {  
 SyntaxKind kind;  
 string val;  
 int line;  
 int column;  
 };  
   
   
 string syntaxTokenToString(SyntaxToken token);  
 string syntaxKindToString(SyntaxKind kind);  
 void printSyntaxToken(SyntaxToken token);  
   
 #endif