DEPARTMENT OF COMPUTER SCIENCE, TECHNISCHE UNIVERSITÄT KAISERSLAUTERN
COMPILERS AND LANGUAGE PROCESSING TOOLS - SS17

A Minijava to μ-LLVM Translator

Exercise 4

Group 03
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OVERVIEW

In this report, we describe our group's Translator from Minijava to μ-LLVM. The resulting Translator is able to translate the following statements and expressions: Block, StmtIf, StmtWhile, StmtReturn, StmtPrint, StmtExpr, StmtAssign, ExprBinary, ExprUnary, BoolConst, VarUse, Number, as well as ArrayLookup, ArrayLength, ExprNull, NewIntArray.
The translator passes all test cases provided in the exercise' template and all test cases laid out by the group mates covering further edge cases.
We implemented our solution through the visitor pattern, breaking down the implementation into different classes for order, understandability and especially functionality purposes. Following, we describe the classes' role in the program.

CLASSES' DESCRIPTION

- **Translator**: Contains the Default Visitor Pattern for the following Minijava expressions and statements: MJStmtIf, MJBlock, MJStmtWhile, MJStmtPrint, MJVarDecl, MJStmtAssign. Content of these expressions and statements is handled separately in other classes, again through the visitor pattern. This class also contains the current block into which the expressions are added and the Hashmap for variables' declarations.
- **ExprMatcherR**:Implements the visitor pattern for "MJExpr" . It matches expressions that can occur on the right-hand side of an operation (e.g: MJExprBinary, MJExprNull in an array assignment, MJExprUnary, MJNegate, MJBoolConst, MJNumber, MJVarUse, MJNewIntArray, MJArrayLength, MJArrayLookup).
- **ExprMatcherL**: Implements the visitor pattern for "MJExpr". It matches expressions that can occur on the left-hand side of an operation (e.g: MJVarUse with different types and MJArrayLookup).
- **OperatorMatcher**: Implements the visitor pattern for "Operator" and the operation type being used in a binary expressions (e.g: MJPlus, MJMinus, MJLess, MJAnd, MJDiv, MJTimes).
- **StaticMethods**: Contains static methods being invoked repeatedly throughout the program for handling operations on arrays.

- **TestOutputLLVM**: Class used for testing the program and invoked by the "Main" class in the "frontend" package. It compares the output of the μ-LLVM-generated program with the Minijava program and checks whether the output produced by the μ-LLVM program version and Minijava are equal.

Technical Description

Task 1 - Translation of Statements and Expressions

- **Block**: A Block is a handled as an iterable list of statements. Each statement is matched to its type in the Translator class.

- **StmtIf**: An If-else statement is handled through three different Basic Blocks, respectively the "IF body" (condition true), the "ELSE body" (condition false) and the remaining code. Initially, the if condition is checked and a Branch operation picks the Basicblock where control flow should pass to (if-basic block or else-basic block). After the evaluation of the selected block, the translation process continues for the remaining code.

- **StmtWhile**: A While statement is also handled through three different Basic Blocks: the condition to be checked, the while loop's body and the rest of the code. In every iteration, the condition block containing a Branch statement with the while's condition is checked: if the condition is true, the statements contained in the loop's body are evaluated. Then, we jump back to the condition block and check the condition again. If the condition is false, translation process continues for the rest of the code.

- **StmtAssign** We handle assignment statements by matching expressions that can occur on the left-hand side (ExprMatcherL) and on the right-hand side (ExprMatcherR) by making use of the visitor pattern and overriding the adequate cases as outlined in the Classes Description. Expressions matched on the left or right hand side that are not allowed in the current implementation (e.g: MethodCall or ExprThis throw an error). We also make use of a class "OperatorMatcher", which returns the operator being used in binary expressions. The value of the operand matched on the right-hand side is stored into the address of the left-hand side operand.

- **StmtPrint**: In print statements, we simply match expressions that can occur on the right-hand side and output the operand matched.

- **Variable Declaration**: We allocate all newly declared variables onto the stack with space depending on their type and also store them into a HashMap.

- **VarUse** Here, we distinguish between the usage on left or right hand side (left means store into it, right means load from it). In both cases, we get the corresponding temporary variable definition (Hashmap) and the type (from the Type and Name Analysis, by referring to the variable declaration).

- **UnaryMinus**:We implemented the unary minus expression (ex: -b) through a binary expression, where the expression is multiplied by -1.

- **UnaryNeg**: We implemented the unary negation expression (ex: !b) through a XOR with a true value to invert the boolean value.

Task 2 - Translation of Arrays

- **NewIntArray**: Array instantiation (ex: a = new int[5]) was implemented as suggested in the lecture slides of the course. Let s = array size (ex: 5), b = size of each element of the array (ex: ConstInt(4)). Since we will need to store the array size in position 0, we will then need to allocate the following amount of space (p) onto the heap:

$$p = (s + 1) * b$$

More specifically, we allocate $s+1$ blocks of size b in contiguous heap space for the storage of elements and the array size. Let $e_1...e_n$ be a list of elements that will be contained in the array at a later time, where $n < s$. Then $e_1...e_n$ will be stored in the array according to the following scheme:

value	s	e_1	e_n
position	0	1	n

In order to prevent LLVM from generating random integer values when performing an ArrayLookup operation on an instantiated array containing no value yet, we instantiate all blocks $1...n$ of an array to integer value 0. Finally, we check that the array is not being instantiated with a negative value: this case would rise an HaltWithError in μ-LLVM.

- **Array Length**: Since the length of the array was stored at position 0, we simply get the array address and access the the first value stored on the heap space allocated for the array (hence, we access index 0). We also implemented in-line length returning for a new int array (e.g: System.out.println(new int[5].length) will produce 5), with adequate checks for preventing the length provided to be negative.
- **Array Lookup**: Whenever looking up a value in an array, we check for three cases not to be matched:
  1. **Array instantiated as null**: If an array was assigned a value "null", then an array lookup operation is not meaningful, and an HaltWithError is added.
  2. **Negative Index**: We ensure a negative index was not passed and add an HaltWithError in case that happens.
  3. **Out of bounds index**: We ensure we do not access a value that is beyond the array size by ensuring that for an index i the following always holds: $i < s$ and add an HaltWithError should this condition not be met.

  Should these two cases not be met, then we retrieve the element looked up at index i through the $i+1$ index in the heap space allocated for the array, as the length is stored at position 0.

REFERENCES

[1] We would like to thank our study colleague Joseff for support with bitcasting arrays into the right format.