

McLab Tutorial

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Part 7 – McVM implementation example: if/else construct

- Implementation in interpreter
- Implementation in JIT compiler

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Example-1

Before we start

- McVM is written in C++, but “clean” C++ 😊
- Nearly everything is a class
- Class names start in capital letters
- Typically one header and one implementation file for each class
- Method names are camel cased (getThisName)
- Members are usually private and named m_likeThis

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Example-2

Before we start ...

- Makefile provided
 - Handwritten, very simple to read or edit
- Scons can also be used
- ATLAS/CLAPACK is not essential. Alternatives:
 - Intel MKL, AMD ACML, any CBLAS + Lapacke (eg. GotoBLAS2 + Lapacke)
- Use your favourite development tool
 - I use Eclipse CDT, switched from Vim
- Virtualbox image with everything pre-installed available on request for private use

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Example-3

Implementing if/else in McVM

1. A new class to represent if/else
2. XML parser
3. Loop simplifier
4. Interpreter
5. Various analysis
 - i. Reach-def, live variable analysis
 - ii. Type checking
6. Code generation

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Example-4

1. A class to represent If/Else

- Class IfElseStmt
- We will derive this class from “Statement”
- Form two files: ifelsestmt.h and ifelsestmt.cpp
- Need fields to represent:
 - Test expression
 - If body
 - Else body

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Example-5

ifelsestmt.h

- class IfElseStmt: public Statement
- Methods:
 - copy(), toString(), getSymbolUses(), getSymbolDefs()
 - getCondition(), getIfBlock(), getElseBlock()
- Private members:
 - Expression *m_pCondition;
 - StmtSequence *m_pIfBlock;
 - StmtSequence *m_pElseBlock;

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Example-6

Modify statements.h

- Each statement has a field called `m_type`
- This contains a type tag
- Tag used throughout compiler for switch/case
- `enum StmtType{`
`IF_ELSE,`
`SWITCH,`
`FOR,`
`....`
`};`

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Example-7

2. Modify XML Parser

- Look in `parser.h`, `parser.cpp`
- Before anything happens, must parse from XML generated by frontend
- XML parser is a simple recursive descent parser
- Add a case to `parseStmt()`
 - Look at the element name in the XML
 - If it is "IfStmt", it is a If/Else
- Write a `parseIfStmt()` function

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Example-8

3. Modify transform loops

- McVM simplifies for-loops to a lower level construct
- To achieve this, we need to first find loops
- Done via a depth first search in the tree
- So add a case to this search to say:
 - Search in the if block
 - Search in the else block
 - Return
- `transform_loops.cpp`

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Example-9

4. Add to interpreter

- Always implement in interpreter before implementing in JIT compiler
- It is a simple evaluator: no byte-code tricks, no direct-threaded dispatch etc.
- Add a case to statement evaluation:
 - Evaluate test condition
 - If true, evaluate if block
 - If false, evaluate else block
- `interpreter.cpp` :
 - Case in `execStatement()`
 - Calls `evalIfElseStmt()`

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Example-10

Moment of silence .. Or review

- At this point, if/else has been implemented in the interpreter
- If you don't enable JIT compilation, then you can now run if/else
- Good checkpoint for testing and development

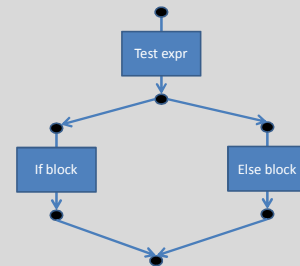
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Example-11

Flow analysis recap

- Compute program property at each program point



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Example-12

Flow analysis recap

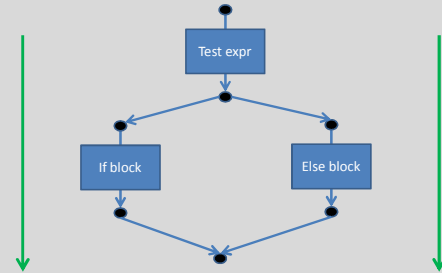
- We want to compute property at each program point
- Typically want to compute a map of some kind at each program point
- Program points are not inside statements, but just before and after
- Usually unions computed at join points
- Can be forward or backwards depending on the analysis

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Example-13

Reaching definitions analysis



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Example-14

McVM reach-defs analysis

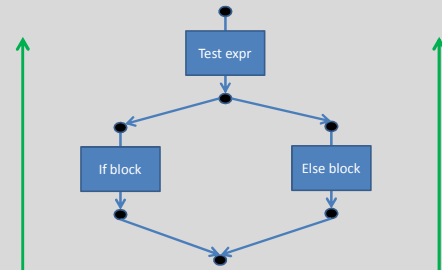
- Look in analysis_reachdefs (.h/.cpp)
- getReachDefs() is an overloaded function to compute reach-defs
- ReachDefInfo class to store analysis info
- If/Else:
 - Record reach-defs for test expression
 - Compute reach-defs for if and else blocks by calling getReachDefs() for StmtSequence
 - Compute union at post-if/else point

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Example-15

Live variable analysis



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Example-16

McVM live vars analysis

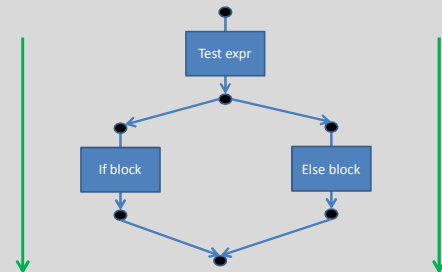
- Look in analysis_livevars (.h/.cpp)
- getLiveVars() is an overloaded function
- LiveVarInfo is a class to store live-vars info
- If/Else:
 - Information flows backwards from post-if/else
 - Flow live-vars through the if and else blocks
 - Compute union at post-test expression
 - Record live-vars info of test expression

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Example-17

Type inference analysis



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Example-18

Type inference

- Look in `analysis_typeinfer (.h/.cpp)`
- `inferTypes()` is an overloaded function to perform type inference for most node-types
- For If/else:
 - Infer type of test expression
 - Infer type of if and else blocks
 - Merge information at post-if/else point

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Example-19

Flow analysis tips

- We define a few typedefs for data structures like maps, sets
 - eg: `VarDefSet`: typedef of set of `IIRNode*` with appropriate comparison operators and allocator
- When trying to understand flow analysis code, start from code for assignment statements
- Pay attention to statements like `return` and `break`

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Example-20

Code generation and LLVM

- LLVM is based upon a typed SSA representation
- LLVM can either be accessed through a C++ API, or you can generate LLVM byte-code directly
- We use the C++ API
- Much of the complexity of the code generator due to SSA representation required by LLVM
- However, we don't do an explicit SSA conversion pass

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Example-21

Code generation in McVM

- SSA conversion is not explicitly represented in the IR
- SSA conversion done while doing code generation
- Assignment instructions are usually not generated directly if `Lvalue` is a symbol
- In SSA form, values of expressions are important, not what they are assigned to
- We store mapping of symbols to values in an execution environment

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Example-22

Compiling if/else

- Four steps:
 - Compile test expression
 - Compile if block (`compStmtSeq`)
 - Compile else block (`compStmtSeq`)
 - Call `matchBranchPoints()` to do appropriate SSA book-keeping at merge point
- Rest of the code is book-keeping for LLVM
- Such as forming proper basic blocks when required

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Example-23