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Processing and analysis of robotic arm control language

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Structure of presentation

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  - Interpreter components and formalisms.
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Part 1

Design of the interpreter

The Robotic Arm Control Language (RACL)

- An interpreted language to control the a robotic arm, a robotic manipulator and cameras.
- Compound of two languages – a LUA and a MELFA-BASIC.
  - LUA – an open-source weakly typed scripting language – common control-flow constructions, mathematical expressions, IO, supports objects [1].
  - MELFA-BASIC – MELFA proprietary language with a BASIC-like syntax – used as a low level language to control the arm [2].

Interpreter components

- The preprocessor.
- The LUA interpreter.
  - Available as OSS.
- The MELFA-BASIC interpreter.
  - Built in an arm controller or in an arm simulator.
  - Significantly simplified.
    - Limited to communication with the arm (MOVS).
    - No flow control or mathematical expressions (IF THE, operator +) of the MELFA BASIC are being used.
    - Sequence of single-line commands.

Interpreter components 2

- The LUA interpreter.
  - Third-party library to interpret LUA - used ”as it is” - just wrapped into RACL interpreter code.
- The MELFA-BASIC interpreter.
  - Only splits the code into single commands that are then passed to simulator or to arm.
  - Simplified MELFA-BASIC accepted by FSM:
    - $(\texttt{COMMAND}'\backslash n'^{+})^{*}\texttt{COMMAND}'\backslash n'^{*}\ [+\ \varepsilon]$
    - `COMMAND` is a set of commands with shape of a symbolic instruction: `MOVJ 10 X1 120`

Interpreter components 3

- The preprocessor
  - Main purpose - combination of MB and LUA.

Source:

```
VAR = 60
#MELFA_BASIC_BEGIN
  MOVJ 10 @VAR1 20
  @VAR2 :- PRINT M_SRV
  MOVJ 30 @VAR1 50
#MELFA_BASIC_END
```

Preprocessed – pure LUA:

```
VAR = 60
INP_VALS[”VAR1”]=VAR1 --input as a value
OOUT_VARS[”VAR2”]=”VAR2” --output as a variable reference
OTHER_MBCall("MOVJ 10 @I[”VAR1”] 20\n@O[”VAR2”] :- PRINT
M_SRV\nMOVJ 30 @I[”VAR1”] 50", INP_VALS,OUT_VARS)
```

Preprocessor complexity

- More complex than a Finite State Transducer.
  - Intuitive proof: FSM can't keep infinite strings.
- More complex than a Pushdown Transducer.
  - Intuitive proof: A stack can store infinite number of infinite strings but it doesn't allow to access them randomly to check appearance of variable name in a set of ”remembered” variables.
- Translation can be computed by LBA (LOA).
  - Length of a list of ”remembered” names and length of a generated output code is linear dependent on length of input.

Part 2

The language analysis

Goals of analysis

- Main goal: Detection of never-ending programs.
  - Undecidable –> only subgoals are being analysed.
  - *(Proof: diagonalization of matrix of binary coded Turing machines and binary coded input strings.)*
- Analysable subgoals of main goal.
  - Detection of potentially infinite loops.
  - Detection of potentially infinite recursion.
- Other notes about analysis.
  - Only single-thread code.
  - Only LUA needs to be analysed.

Potentially infinite looping

- If it starts to loop it will never end.
- We can't decide easily if looping will start.
  - Loop (or recursion) might be in a conditional branch depending on unknown program inputs.
  - Condition of looping might be not satisfied.
  - Probably the easiest way of deciding if looping will start is to execute the program.

Analysis technique I used

- Syntax analysis.
  - Rejects the code with syntactic errors and constructs AST.
  - Used third-party analyser LuaFish.
- Control-flow analysis [3].
  - Construction of control-flow graph from AST.
  - Finding loops in control-flow graph.
- Data-flow analysis [4].
  - Analysis of assignments to variables and their appearance in cond-branch expressions only.

Current analyser prototype

- Converts AST generated by LuaFish to CF.
- Gathers informations about variable assignments and about appearance of variables in conditional branch control expressions.
- Only loop analysis.
- Recursion analysis is not supported yet.
- Objective code is not supported yet.

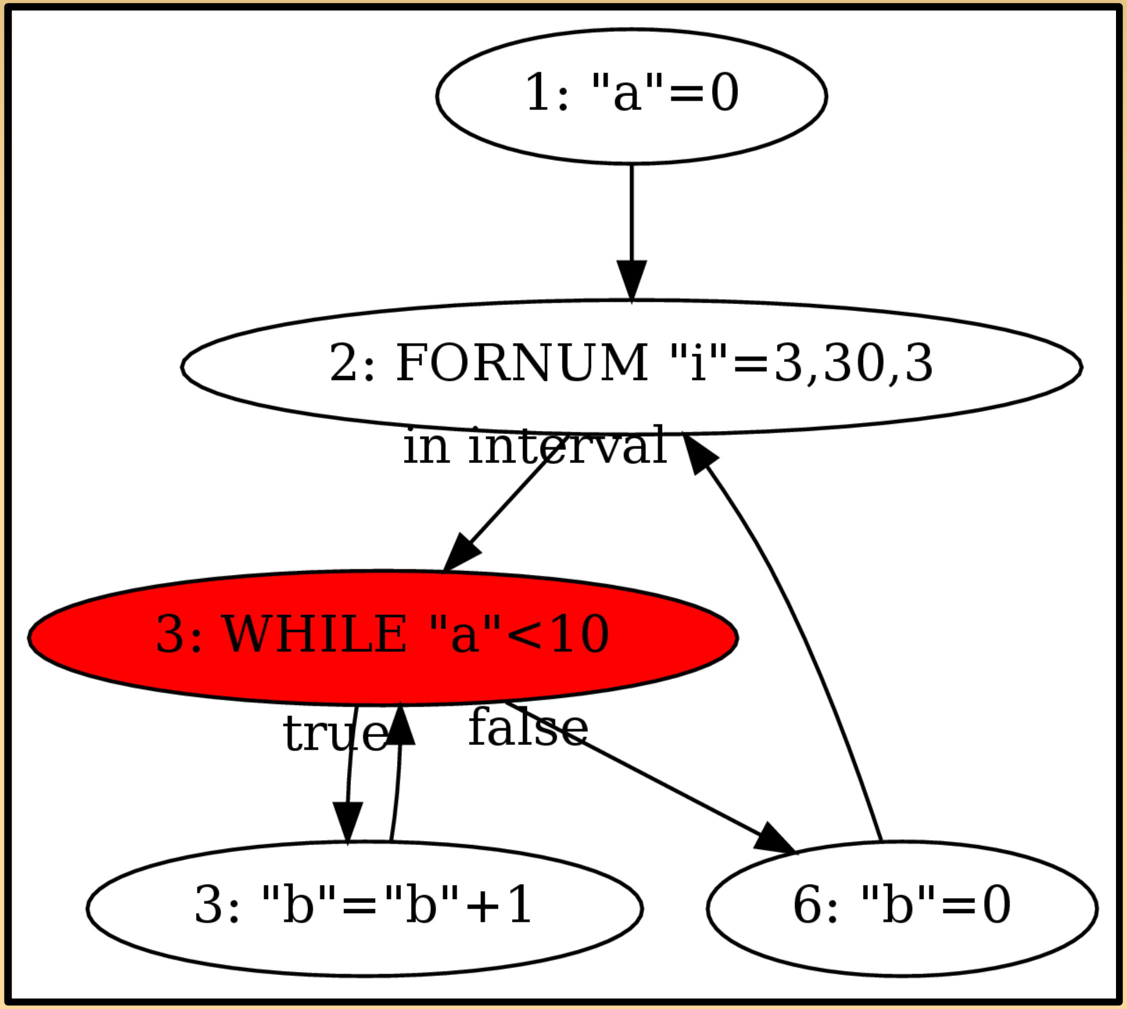
Example of analysis

- Source code

```
a=0
for i= 3,30,3 do
  while a < 10 do  --a is not modified in the loop body
    b = b + 1
  end
  b = 0
end
```

Example of analysis

- CF graph with highlighted analysis result



Difficulties of LUA analysis

- Variables without prior definition.
  - They have a default value – nil.
  - nil is not like a NULL pointer – it can be casted to number, boolean or string.
  - Variables with all possible names ”exist”.
- Variables are global by default.

```
if x > 10 then
  a = 5
end
--a has value 5 here
```

Difficulties of LUA analysis

- Objective code.
  - Assigning correct data to object methods.
- Multiassignments.

```
a,b,c = x,u --c is set to nil
```

  - We have to check that all variables have right-side value. Otherwise they will be set to *nil*.

References

- [1] Ierusalimschy R. , Figueiredo L. H., Celes W.: Lua 5.1 Reference Manual, online <http://www.lua.org/manual/5.1/>, August 2006, cit. Dec. 2011.
- [2] Guerrero J.: COSIMIR MELFA BASIC IV, online <http://dmi.uib.es/~jguerrero/instMelfa.pdf>, September 2004, cit. Dec. 2011.
- [3] Kolektiv: Control flow analysis, online <http://en.wikipedia.org/wiki/Control_flow_analysis>, May 2011, cit. Dec.2011.
- [4] Nielson F, Nielson H., Hankin Ch.: Principles of Program Analysis: Data Flow Analysis, online <http://www2.imm.dtu.dk/~riis/PPA/slides2.pdf>, 2005, cit. Dec.2011.

The End

Thank you for your attention.