Detection of Variable Misuse Using Static Analysis Combined with Machine Learning

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Algorithmic errors

BadCopyPaste

```
if (g1 != IntPtr.Zero)
    m_scene.actor_name_map.TryGetValue(g1, out p1);

if (g2 != IntPtr.Zero)
    m_scene.actor_name_map.TryGetValue(g1, out p2);
```

SwappedArgument

```
ClassifyStandard(destination, source);
ClassifyStandard(source, destination);
```

- a lot of unclassifiable errors;
- static analyzers use heuristics to find such errors;
- only small subset of alg. errors can be detected;
- useful information is contained in names of classes, methods, variables, etc.

Slots and candidates

BadCopyPaste

```
if (g1 != IntPtr.Zero)
    m_scene.actor_name_map.TryGetValue(g1, out p1);

if (g2 != IntPtr.Zero)
    m_scene.actor_name_map.TryGetValue(g1, out p2);
```

- *slot* - read access to a variable;
- *candidate for a slot* - variable, field and property which can be used in slot from compiler point of view;
- *cand(5)* $= \{\text{g1}, \text{g2}\}$.

Algorithmic error detection

Goal

To generalize variable misuse detection methods.

VarMisUse problem

Detect if the used one candidate is wrong for a given slot.

Approach

Neural network application for a graph representation of a program. The representation includes information from the both natural language in code and multiple levels of static program analysis.

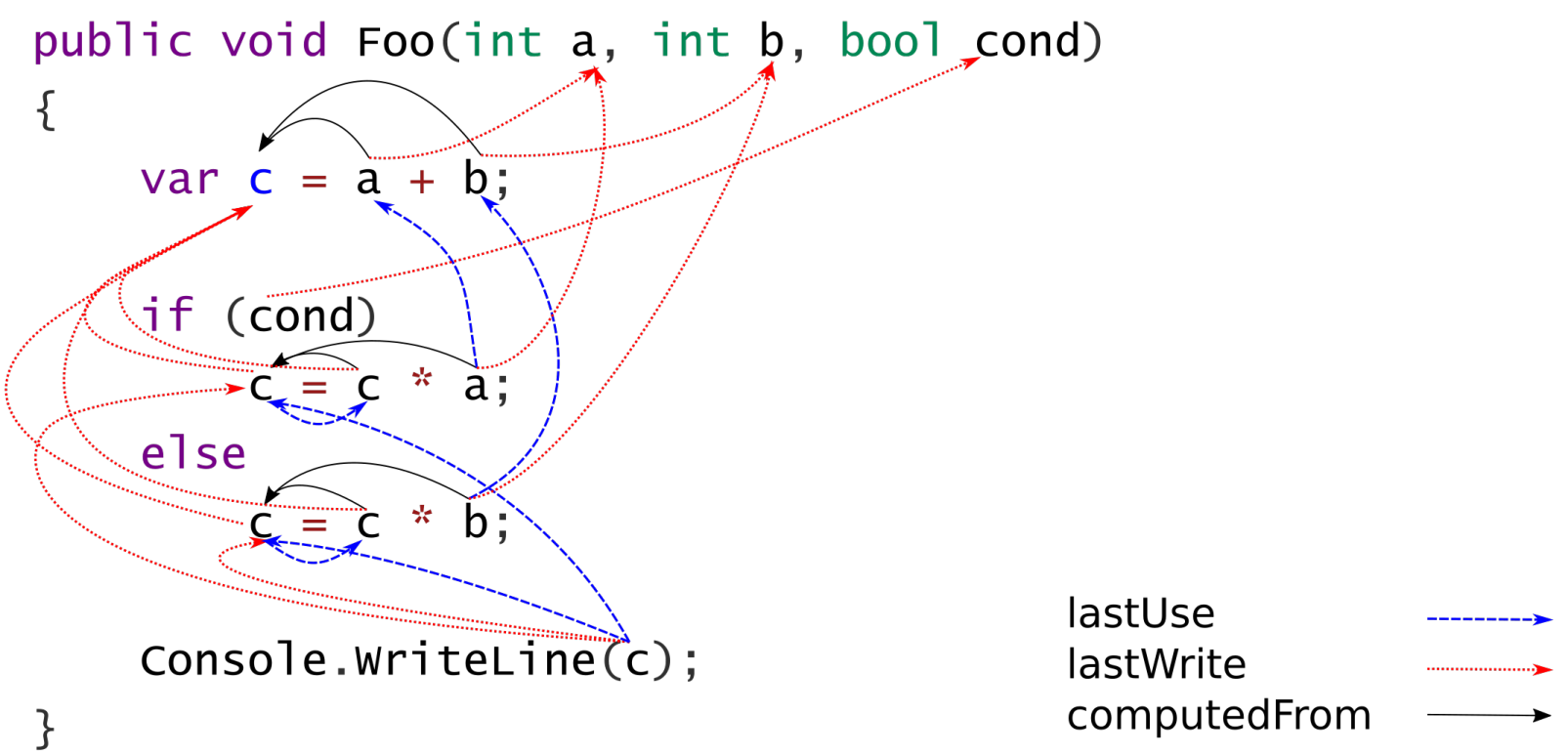
[1] **Learning to Represent Programs with Graphs**
M. Allamanis and M. Brockschmidt and M. Khademi

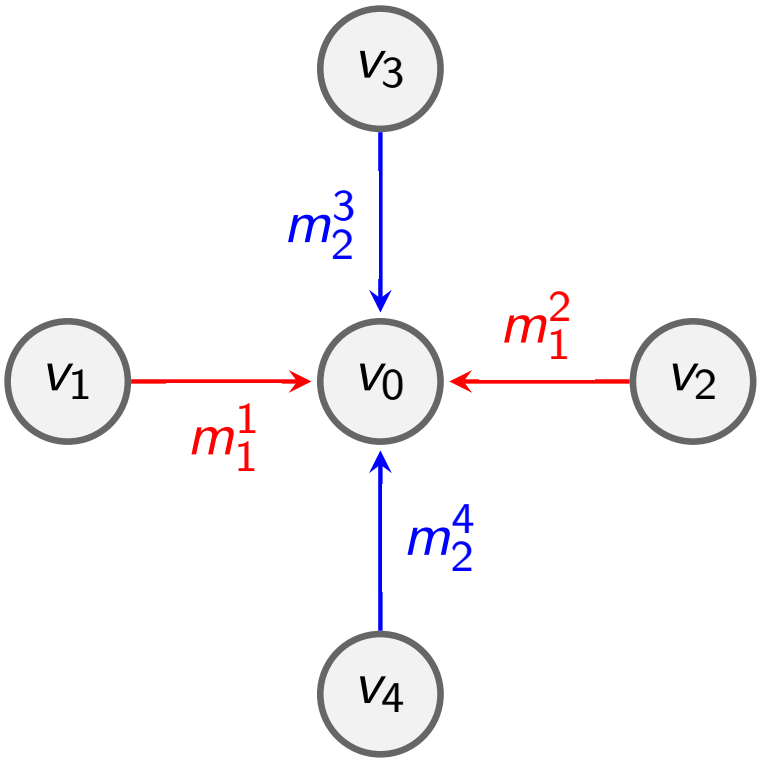
Analysis phases

1. Data preparation
   - slots selection;
   - finding of candidates for each slot;
   - computation of edges for each candidate.
2. Data processing
   - building of graphs for candidates;
   - features encoding.
3. Prediction of candidate's probabilities
4. Decision on the correctness of the used candidate

Program representation

The program graph is based on an abstract syntax tree with additional edges: LastWrite, LastUse, LastLexicalUse, NextOperand, FormalArgs, ComputedFrom.





- for each graph node associate a representation vector $h^{(v)}$;
- messages are passed along edges;
  $m_k^v = f_k(h^{(v)})$ - the message from node v of kind k;
- f_k - linear learnable function;
- the state
  $h^{(v)} = RNN(m_{in}, h^{(v)})$ is updated a fixed number of times.

Features of node

Tokens Node

- Token
- SyntaxKind
- Type (*if exists*)

AST Node

- Unknown token
- SyntaxKind
- Type (*if exists*)

Embedding

- split tokens by *CamelCase* and *under_scope*
- train **word2vec** on a big corpus of source code;

Improvements

Neural network architecture

- **GRU**;
- **LSTM**.

Usage of a **LSTM** cell shows slightly better results ($\sim 3\%$).

Graph representation

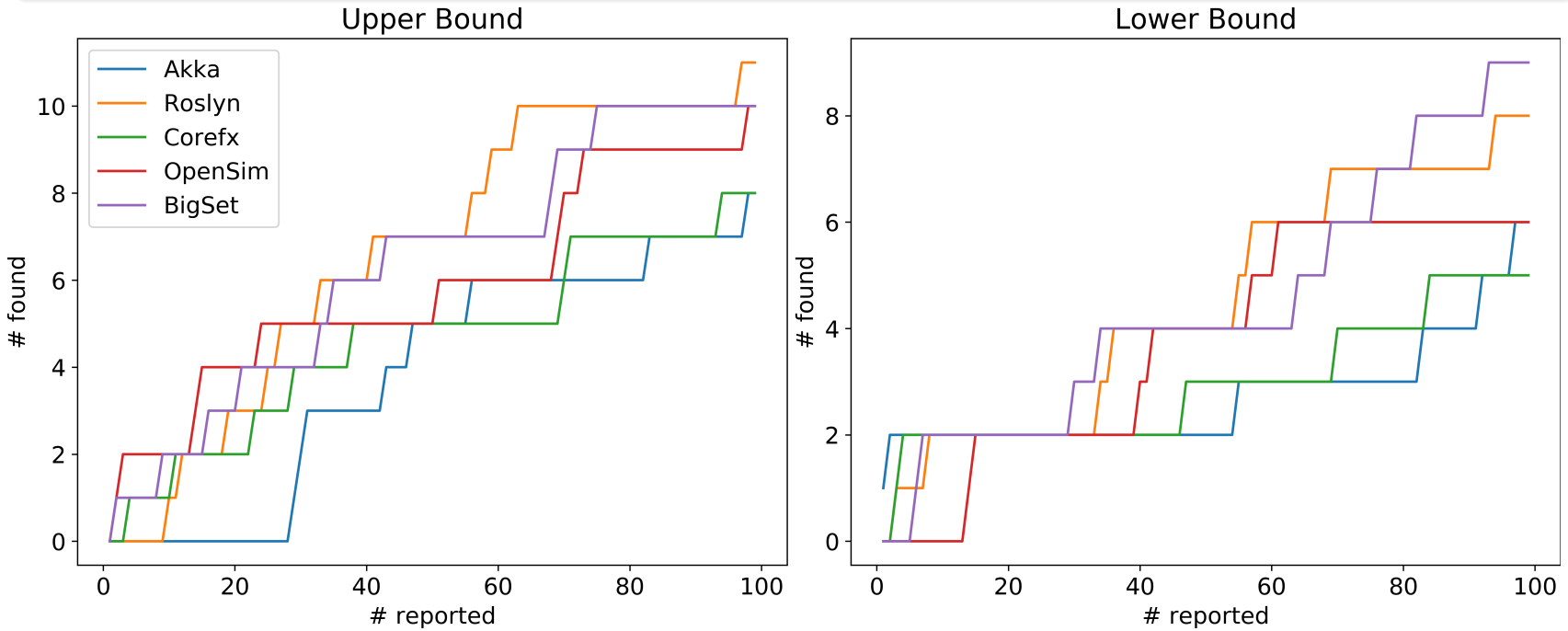
We remove **AST** nodes and edges from the representation.

- 3 times smaller graph size;
- more than 3 times faster training;
- the same score.

Detected errors
The example of ambiguously classified warning

Error criteria

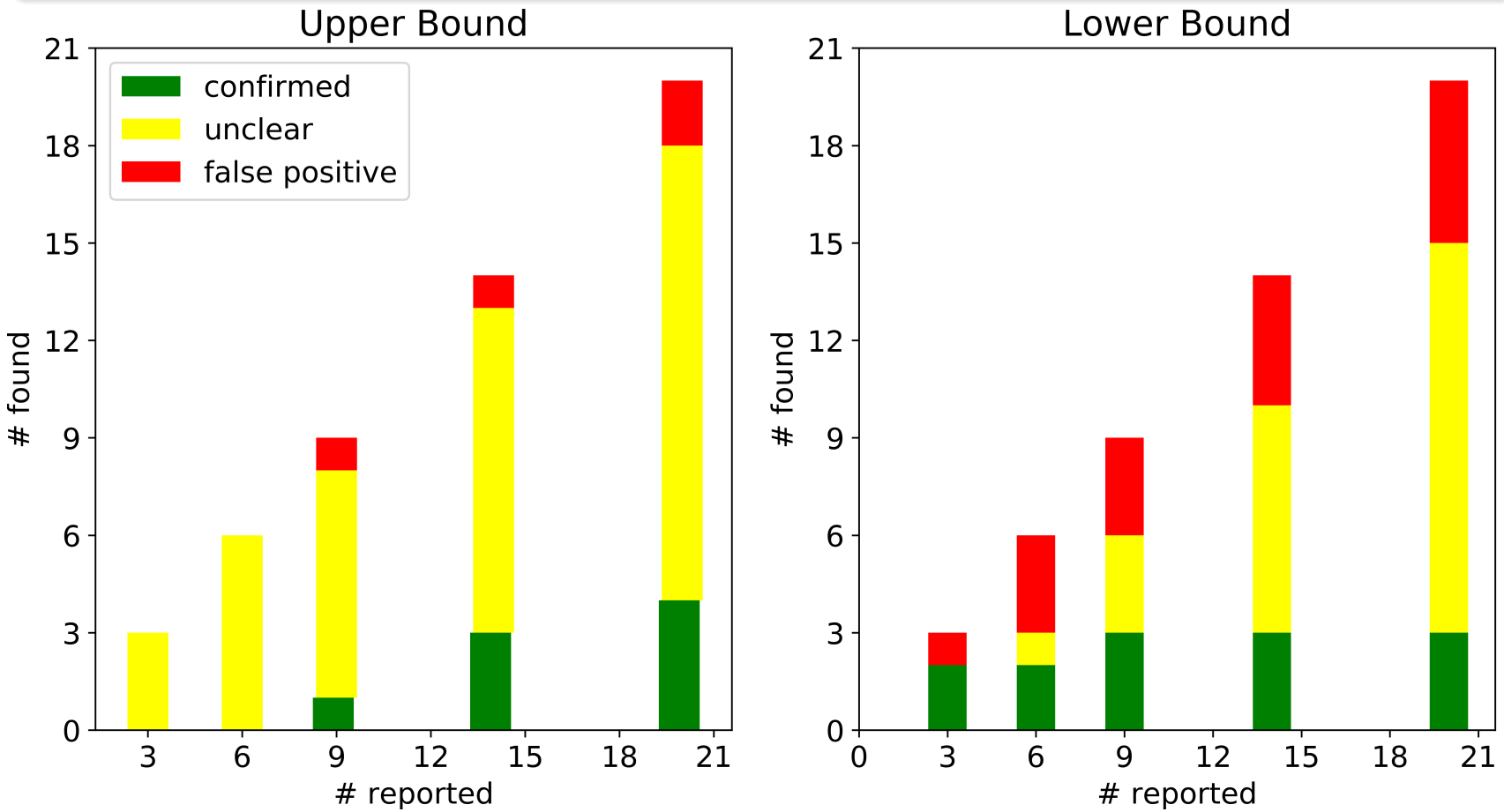
1. Exactly right candidate
2. Critical Zone
3. Lower Bound
4. Upper Bound



Experiment

Real test

25 VarMisUse errors were added in OpenSim project.



Detected errors

```
public GenericMonitor(
            Scene scene,
            string name,
            string friendlyName,
            Func<GenericMonitor, double> getValueAction,
            Func<GenericMonitor, string> getFriendlyValueAction) {
    Scene = scene;
    Name = name;
    FriendlyName = name;
    m_getFriendlyValueAction = getFriendlyValueAction;
    m_getValueAction = getValueAction;
}
...
m_staticMonitors.Add(new GenericMonitor(m_scene,
    name: "TimeDilationMonitor", friendlyName: "Time Dilation",
    m => m.Scene.StatsReporter.LastReportedSimStats[0],
    m => m.GetValue().ToString()));
```

Detected errors
The example of ambiguously classified warning

```
public bool AckPacket(uint packet) {
  if (!complete) {
    if ((Data.Length - DataPointer) > 1000) {
      byte[] transferData = new byte[1000];
      Array.Copy(Data, DataPointer, transferData, 0, 1000);
      Client.SendXferPacket(XferID, Packet, transferData, isTaskInventory);
      Packet++;
      DataPointer += 1000;
    }
    else {
      byte[] transferData = new byte[Data.Length - DataPointer];
      Array.Copy(Data, DataPointer, transferData, 0, Data.Length - DataPointer);
      uint endPacket = Packet |= (uint) 0x80000000;
      Client.SendXferPacket(XferID, endPacket, transferData, isTaskInventory);
      Packet++;
      DataPointer += (Data.Length - DataPointer);
      complete = true;
    }
  }
  return complete;
}
```

Results
Accuracy for different projects

Project	Akka.Net	Cassandra	Lucene	Opensim	Netoffice	Openbve	Corefx	Roslyn
Accuracy	91.3%	96.1%	87.5%	83.6%	99.9%	83.6%	83.6%	86.2%

- better results for projects with small average method length;
- average numbers of candidates is 3.6;
- various training set allows to find more real errors.

Future work

- replacing syntax connection with the results of another compiler analyse;
- usage **PDG** to represent program;
- usage another neural network architecture.