

Evolution of specifications in Alloy

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Problem – Specifications are hard

- Specification Objective
 - Formally expressible
 - Captures key points of Specification

Problem – Spanning tree model

- 3 relations
 - General Relation
 - Tree1 Relation
 - Tree2 Relation
- Tree1 and Tree2 spanning trees of General
- Tree1 \neq Tree2

Alloy API – Where no man has gone before

- Signatures

- `PrimSig nodeSig = new PrimSig("NODE");`

- Relations

- `Expr genRel = nodeSig.addField("genRel", nodeSig.setOf());`

Alloy API – The revenge

- Named variables
 - Decl testRoot = nodeSig.oneOf("TestRoot");
 - Decl rootRel = ExprBinary.Op.ARROW.make(null,
– Null, nodeSig, NodeSig).setOf("rootRel")
- Expressions
 - Expr checkRoot = rootRel.get().join(testRoot.get()).no();

Evolutionary method

- Using package ECJ
 - Java based
- Choose some primitives
 - Alloy operators
 - Signatures
 - Relations
- Create random programs based on primitives
- Rank them based on a fitness function
- Breed them together based on fitness

Fitness

- 0 is perfect, higher means worse
- Form valid Alloy Expression
 - All arities must match
 - No Unary relation = Binary Relation
 - 0.75 fitness
- Form satisfiable Alloy Expression
 - Run show gets results
 - 0.50 fitness

Fitness – the sequel

- Compare Examples and Counter Examples
 - Count Examples
 - Count Counter Examples
 - $0.25 - ((\text{Examples} - \text{Counter Examples}) / 100)$

Fitness – A New Hope

- Examples
 - Just run the generated Alloy Expr
- Counter Examples
 - Check works on Expr
 - Currently
 - Run model and !ValidationExpression
 - Future
 - Check model Implies ValidationExpression

Results

- Runs quickly
 - Using SAT4J
 - On laptop
- Max fitness
 - .25
 - Examples = Counter Examples

Results -Good news

- Population learning takes place
 - Generation 0
 - Many Alloy malformations
 - Arity mismatch
 - Later
 - Malformations mostly die out
 - Overall fitness approaches .25
 - Crossover does preserve something

Results – I did what?

- On size 3 models
 - Find over 1000 examples
 - Find over 1000 counter examples
- Something's not right
- Example vs Counter Example does nothing

Summary

- Basic groundwork laid
- As of Dec 9th 6:30am it runs!
- Executes quickly enough
- Crossover and mutation don't seem to destroy everything
- Evolution does occur as much as the Fitness function encourages it

Future work

- Why 1000 examples on size 3 world?
- Add ForOne, ForAll, ForNone support
- Refine fitness measure
 - More granular verification conditions?
 - Specific test cases?

Appendix – Evolution Nitty Gritty

Nonstandard Evolutionary Representation

- Linear “tree”
 - Nodes
 - Unique address
 - Have “argument” children
 - Pointer to next Node

Evolutionary primitives

- Unary Operator Expressions
 - Lone
 - Some
 - No
 - Closure
 - Not

Evolutionary primitives

- Binary Operator Expressions
 - And
 - Equal
 - Implies
 - In
 - Join
 - Minus
 - Or
 - Plus

Evolutionary primitives

- Reference Operator
 - Allows reference to another expression tree
 - Example
 - Expr a
 - Expr b
 - And
 - Address a
 - Address b

Evolutionary primitives

- Signatures
 - Node only current one
- Relations
 - General
 - Node → Node
 - Tree1
 - Node → Node
 - Tree2
 - Node → Node