

Generating Range Fixes for Software Configuration

Yingfei Xiong*

Arnaud Hubaux

Steven She
Krzysztof Czarnecki

Peking
University
China

University of
Namur
Belgium

University of
Waterloo
Canada

* The work was done when Yingfei was at University of Waterloo

Variability Models & Configurators



Configuration

The image displays three overlapping screenshots of configuration tools. The top-left screenshot shows the 'unnamed2* - eCos Configuration Tool' with a table of configuration options:

Configuration	Value
Object Pool Configuration	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Object Pool Size	8
Use Pre-Allocation	<input checked="" type="checkbox"/>
Pre-Allocation Size	10
Allocation Time	<input type="checkbox"/> Startup <input checked="" type="checkbox"/> First Access <input type="checkbox"/> Idle

The bottom-left screenshot shows a terminal window for 'Linux Kernel v2.6.29 Config' with a list of generic driver options, including 'Connector - unified use', 'First Android Driver', 'Memory Technology Device', 'Parallel port support', 'Block devices', 'Misc devices', 'ATA/ATAPI/MFM/RLL support', 'SCSI device support', and 'Serial ATA (prod) and Parallel ATA (experimental) drivers'. The bottom-right screenshot shows the 'Weather Station Example' feature tree in a GUI, with a detailed view of the 'Pressure' feature selected.

Linux Kconfig,
eCos CDL,
pure::variants,
...

Variability Models

eCos Configurator - Errors

The screenshot shows the eCos Configuration Tool window titled "unnamed3* - eCos Configuration Tool". The interface includes a menu bar (File, Edit, View, Build, Tools, Help) and a toolbar with various icons. The main area is divided into a configuration tree on the left and a property details pane on the right.

The configuration tree shows the following structure:

- Configuration
 - Object Pool (v3_0)
 - Buffer Size (KB): 4
 - Object Size (Byte): 512
 - Pool Size: 8
 - Preload (checked)
 - Preload Size: 10
 - Allocation_Time
 - Startup (unchecked)
 - First Access (checked)
 - Idle (unchecked)

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

Property	Value
Value	10
Default	10
Flavor	data
Requires	PreloadSize <= PoolSize
DefaultValue	10

eCos Configurator - Inactive Options

The screenshot shows the eCos Configuration Tool interface. The left pane displays a configuration tree for 'v3_0' with the following items:

- Object Pool (v3_0)
 - Buffer Size (KB) (4)
 - Object Size (Byte) (512)
 - Pool Size (8)
 - Preload (checked)
 - Preload Size (10)
 - Allocation_Time
 - Startup (disabled)
 - First Access (checked)
 - Idle (unchecked)

The right pane shows a table of properties for the selected 'Startup' item:

Property	Value
Macro	Startup
Enabled	False
Flavor	bool
Implements	Allocation_Time
ActiveIf	PreloadSize <= PoolSize / 2

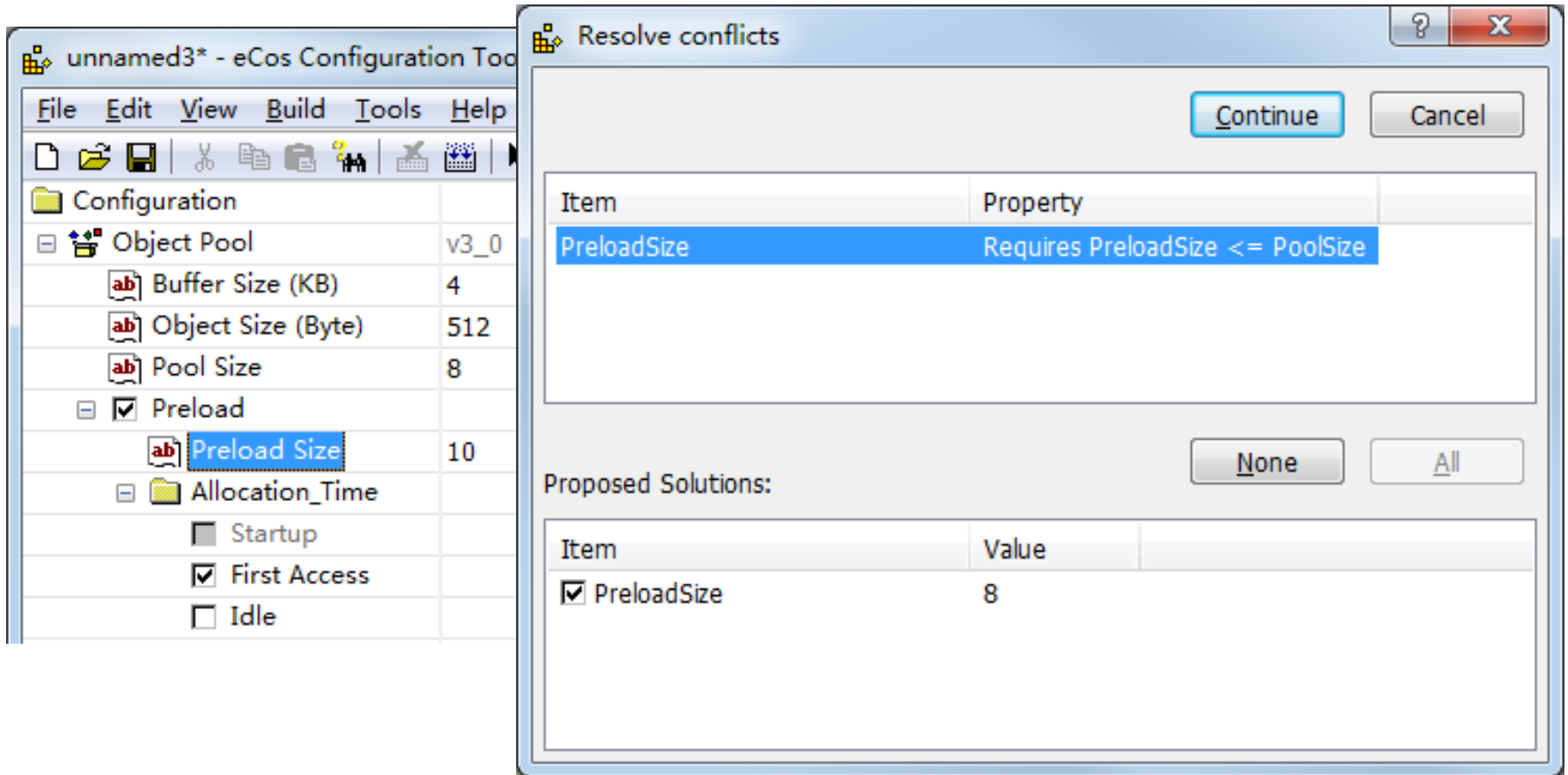
A red callout bubble with the text 'disabled' points to the 'Startup' checkbox in the configuration tree.

Error resolution and option activation both need to resolve violation of constraint.

Survey

- 97 Linux users and 9 eCos users
- Resolving a violation is hard
 - 20% Linux users need "a few dozen minutes" to activate an option in average
 - 56% eCos users consider activation to be a problem

eCos Configurator



Essentially, fixes work for both resolving errors and activating options

Fix Incompleteness

The image shows two windows from the eCos Configuration Tool. The left window, titled 'unnamed3* - eCos Configuration Tool', displays a configuration tree. The right window, titled 'Resolve conflicts', shows a conflict resolution dialog.

Configuration Tool Configuration:

Item	Value
Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
Preload	<input checked="" type="checkbox"/>
Preload Size	10
Allocation_Time	
Startup	<input type="checkbox"/>
First Access	<input checked="" type="checkbox"/>
Idle	<input type="checkbox"/>

Resolve Conflicts Dialog:

Item: PreloadSize
Property: Requires PreloadSize <= PoolSize

Proposed Solutions:

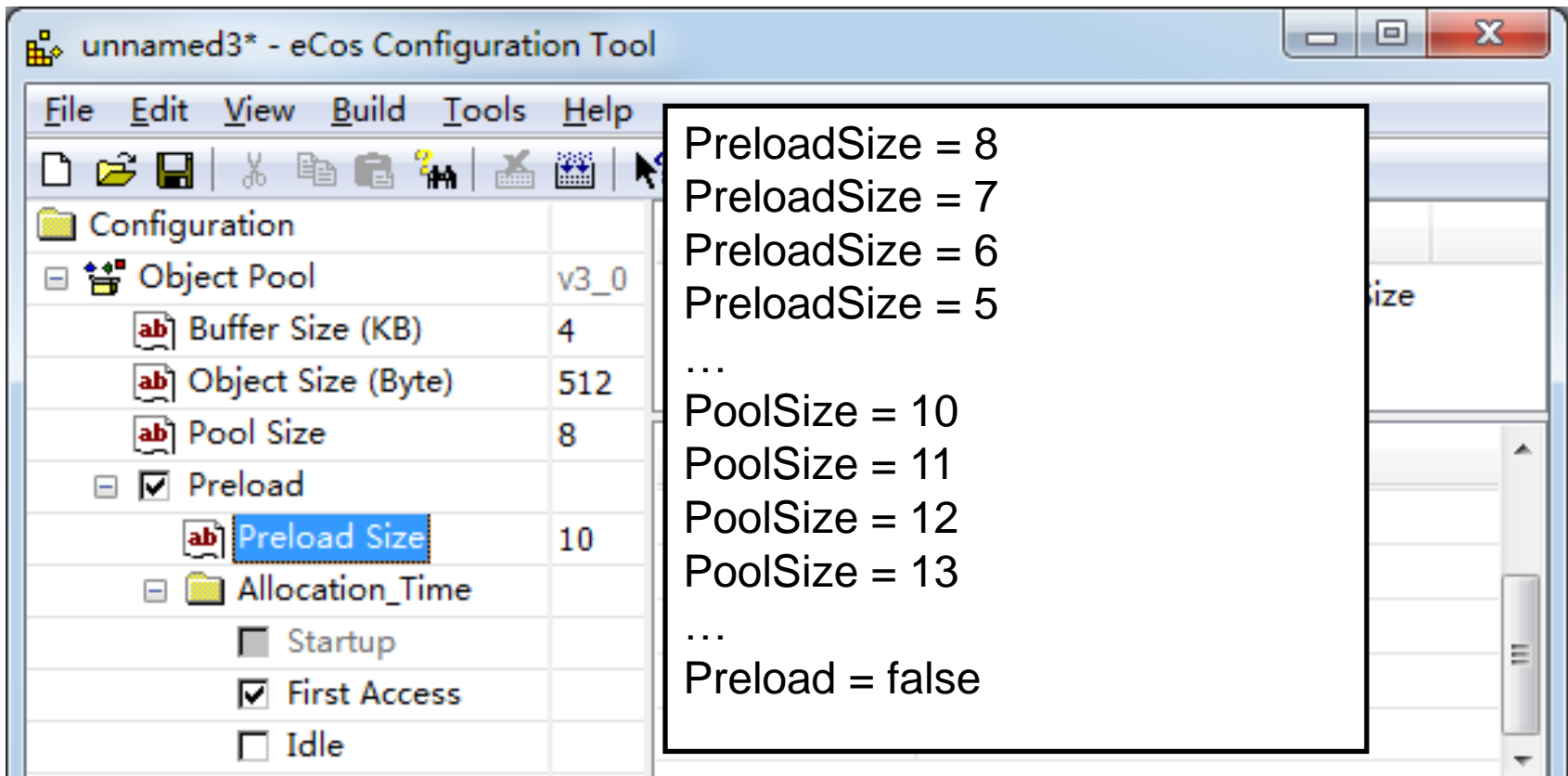
Item	Value
<input checked="" type="checkbox"/> PreloadSize	8

Annotations:

- A red box with the text "Increase to any value ≥ 10 " points to the "PreloadSize" property in the "Resolve Conflicts" dialog.
- A red box with the text "Further decrease to any value ≤ 8 " points to the "8" value in the "Proposed Solutions" table.
- A red box with the text "Disable" points to the "Preload" checkbox in the configuration tool.
- Red circles highlight the "8" value in the "Pool Size" row of the configuration tool and the "8" value in the "Proposed Solutions" table.

78% eCos users have encountered situations where the proposed fix is not useful

How to complete fixes



The screenshot shows the 'eCos Configuration Tool' window. The left pane displays a configuration tree with the following items:

Configuration Item	Value
Configuration	
Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
Preload	<input checked="" type="checkbox"/>
Preload Size	10
Allocation_Time	
Startup	<input type="checkbox"/>
First Access	<input checked="" type="checkbox"/>
Idle	<input type="checkbox"/>

The right pane shows a list of fixes:

- PreloadSize = 8
- PreloadSize = 7
- PreloadSize = 6
- PreloadSize = 5
- ...
- PoolSize = 10
- PoolSize = 11
- PoolSize = 12
- PoolSize = 13
- ...
- Preload = false

Our Solution – Range Fixes

The screenshot shows the 'eCos Configuration Tool' window. The left pane displays a tree view of the configuration. The right pane shows the properties for the selected 'Preload Size' item. A text box is overlaid on the right pane, containing the following constraints:

- [PreloadSize <= 8]
- [PoolSize >= 10]
- [Preload = false]

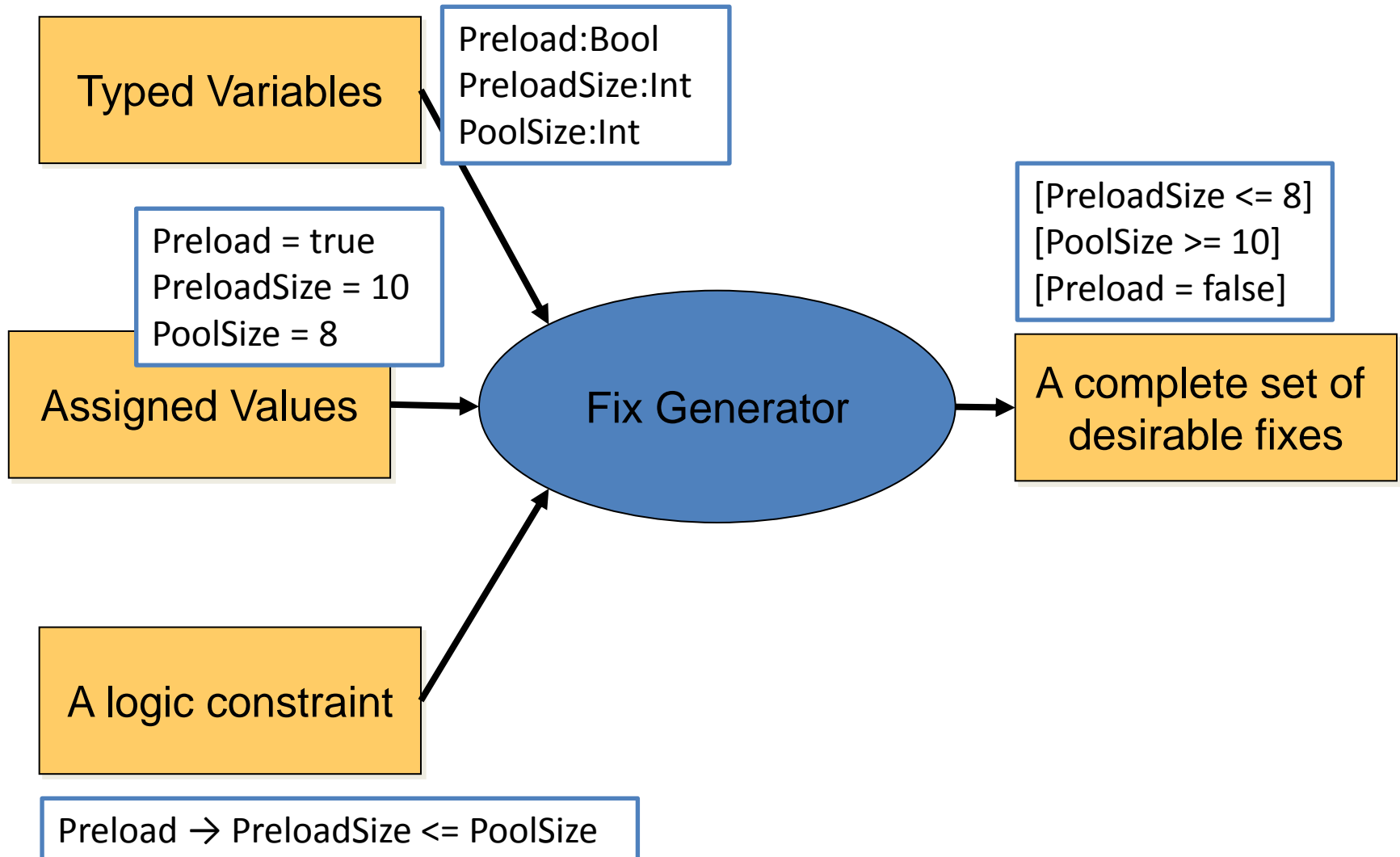
Item	Property
PreloadSize	Requires PreloadSize <= PoolSize
Flavor	data
Requires	PreloadSize <= PoolSize
DefaultValue	10

Our Contributions

- Defining the range fix generation problem
 - Three desirable properties of range fixes
- Proposing a range fix generation algorithm
- Exploring the constraint interaction problem
 - Summarizing and adapting three strategies used in existing work
 - Comparing the strategies empirically

Fix Generation Problem

– a General Definition



Desired Properties of Fixes

Correctness	Minimality of variables	Maximality of ranges
Any change represented by a range fix will satisfy the constraint	There is no way to change a subset of variables to satisfy the constraint	A range fix represents the maximal ranges over the variables
A desirable one: [PreloadSize <=8]		
Undesirable ones		
[PreloadSize <= 9]	[PreloadSize <=8, Preload = false]	[PreloadSize <=7]

Algorithm

- Based on Reiter's theory of diagnosis
- Please check the paper for the details

Constraint Interaction

The screenshot shows the 'eCos Configuration Tool' window. The main configuration table is as follows:

Item	Property
Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
Preload	<input checked="" type="checkbox"/>
Preload Size	10
Allocation_Time	
Startup	<input type="checkbox"/>
First Access	<input checked="" type="checkbox"/>
Idle	<input type="checkbox"/>

A text box with a black border is overlaid on the 'Preload Size' row, containing the following constraints:

- [PreloadSize <= 8]
- [PoolSize >= 10]
- [Preload = false]

Below the text box, the 'PreloadSize' property is shown with a 'Requires' constraint: `Requires PreloadSize <= PoolSize`. The 'DefaultValue' for PreloadSize is 10.

Constraint Interaction

unnamed3* - eCos Configuration Tool

File Edit View Build Tools Help

Configuration

Item	Property
Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	12
Preload	<input checked="" type="checkbox"/>
Preload Size	10
Allocation_Time	<input type="checkbox"/>
Startup	<input type="checkbox"/>
First Access	<input checked="" type="checkbox"/>
Idle	<input type="checkbox"/>

Property	Value
File	unnamed3_install/include/pkgconf/hal.h
Macro	PoolSize
Value	12
Default	0
Flavor	data
Requires	PoolSize == BufferSize * 1024 / ObjectSize

Causing another error

Increase PoolSize

Interacting constraint

Elimination

Eliminate all changes that will violate other constraints

The screenshot shows the 'eCos Configuration Tool' window for 'unnamed3*'. The configuration table is as follows:

Item	Property
Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
Preload	<input checked="" type="checkbox"/>
Preload Size	10
Allocation_Time	
Startup	<input type="checkbox"/>
First Access	<input checked="" type="checkbox"/>
Idle	<input type="checkbox"/>

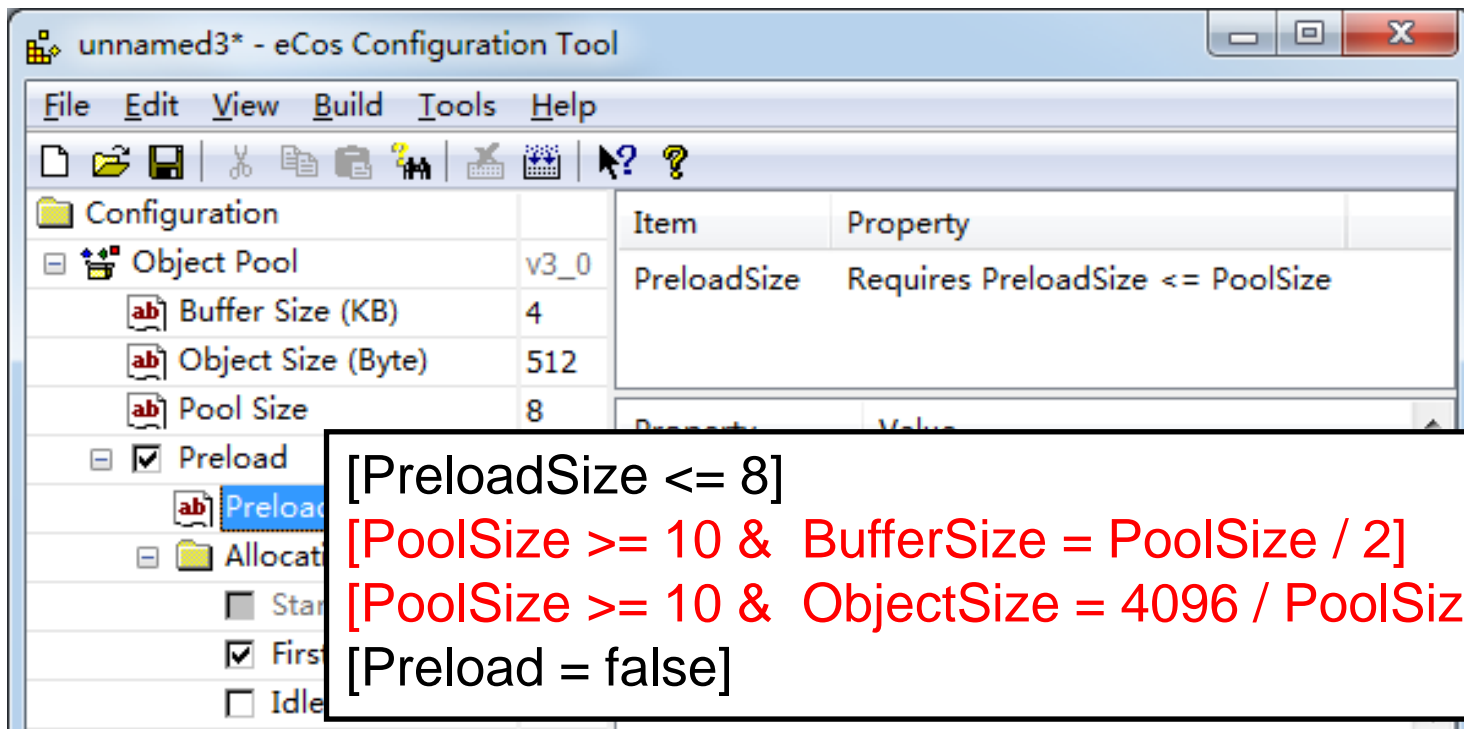
A callout box highlights the following constraints:

- [PreloadSize <= 8]
- ~~[PoolSize >= 10]~~
- [Preload = false]

The 'Preload Size' property is highlighted in blue in the configuration table. The 'Preload' checkbox is checked. The 'Preload Size' value is 10. The 'Pool Size' value is 8. The 'Preload Size' value (10) is greater than the 'Pool Size' value (8), which violates the constraint [PreloadSize <= PoolSize].

Propagation

Propagate the change along other constraints



The screenshot shows the 'eCos Configuration Tool' window with the following configuration parameters:

Item	Property
Object Pool	v3_0
PreloadSize	Requires PreloadSize <= PoolSize
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8

The callout box contains the following constraints:

- [PreloadSize <= 8]
- [PoolSize >= 10 & BufferSize = PoolSize / 2]
- [PoolSize >= 10 & ObjectSize = 4096 / PoolSize]
- [Preload = false]

Comparison of Strategies

	Ignorance	Elimination	Propagation
Execution time	Shortest	Short	Possibly long
Complexity of fix lists	Simple	Simplest	Possibly complex
Introduction of new errors	Possible	Never	Never
Fix completeness	Complete (for one constraint)	Incomplete	Complete (for all constraints)

Experiments

- Source
 - Version histories from 5 open source projects
- Steps
 - Compare each pair of consecutive versions
 - Replay the user changes in different orders
 - Generate fixes for the violations and compare with user changes

Execution Time

	Ignorance	Elimination	Propagtion
Execution time	Average: 17ms Maximum: 20ms	Average: 20ms Maximum: 30ms	Average: 50ms Maximum: 250ms
Complexity of fix lists	Simple	Simplest	Possibly complex
Introduction of new errors	Possible	Never	Never
Fix completeness	Complete (for one constraint)	Incomplete	Complete (for all constraints)

Our algorithm is sufficiently fast for each strategy

Complexity of fix lists

	Ignorance	Elimination	Propagtion
Execution time	Average: 17ms Maximum: 20ms	Average: 20ms Maximum: 30ms	Average: 50ms Maximum: 250ms
Complexity of fix lists (Number of variables in a list)	Max: 4 Median: 2 Average: 2.2	Max: 4 Median: 2 Average: 1.64	Max: 58 Median: 2 Average: 8.0
Introduction of new errors	Possible	Never	Never
Fix completeness	Complete (for one constraint)	Incomplete	Complete (for all constraints)

In propagation, 83% of the fix lists contain less than 10 variables

Introduction of new errors

	Ignorance	Elimination	Propagtion
Execution time	Average: 17ms Maximum: 20ms	Average: 20ms Maximum: 30ms	Average: 50ms Maximum: 250ms
Complexity of fix lists (Number of variables in a list)	Max: 4 Median: 2 Average: 2.2	Max: 4 Median: 2 Average: 1.64	Max: 58 Median: 2 Average: 8.0
Introduction of new errors	44% of all violations	Never	Never
Fix completeness	Complete (for one constraint)	Incomplete	Complete (for all constraints)

Fix completeness

	Ignorance	Elimination	Propagtion
Execution time	Average: 17ms Maximum: 20ms	Average: 20ms Maximum: 30ms	Average: 50ms Maximum: 250ms
Complexity of fix lists (Number of variables in a list)	Max: 4 Median: 2 Average: 2.2	Max: 4 Median: 2 Average: 1.64	Max: 58 Median: 2 Average: 8.0
Introduction of new errors	44% of all violations	Never	Never
Fix completeness (coverage of user changes)	100%	57%	100%

eCos configurator: 73%

Conclusion

- Fix completenss can be achieved by organizing them into range fixes
- Range fixes can be generated automatically and efficiently
- Three strategies for constraint interaction
 - No absolutely best solution
 - Propagation strategy gives relatively better results than the other two

Thank you for your attention!

EccFixer: <http://gsd.uwaterloo.ca/eccfixer>