

Generating Range Fixes for Software Configuration

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Variability Models & Configurators



Configuration

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

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

The top-right screenshot is titled 'Weather Station Example' in the Eclipse Platform. It shows a hierarchical tree diagram of a 'Weather Station' configuration with nodes for 'Sensors', 'Output', and 'Device'. The 'Sensors' node is expanded to show 'Temperature', 'Pressure', 'PC Data transfer', 'LCD', and 'Trace'. The 'Pressure' node is further expanded to show 'USB', 'Serial', and 'Protocol'. A 'Properties' window for the 'Pressure' node is also visible, showing details like 'Unique ID', 'Unique Name', and 'Visible Name'.

The bottom-left screenshot is titled 'Linux Kernel v2.29 Configuration' and shows a terminal window with a list of configuration options for the Linux kernel, such as 'Generic Driver Options', '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'.

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

The property details pane on the right shows the following information for the selected "Preload Size" property:

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 Configurator 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 tree view on the left and a property table on the right.

Configuration Tree:

- Configuration
 - 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)

Property Table:

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

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

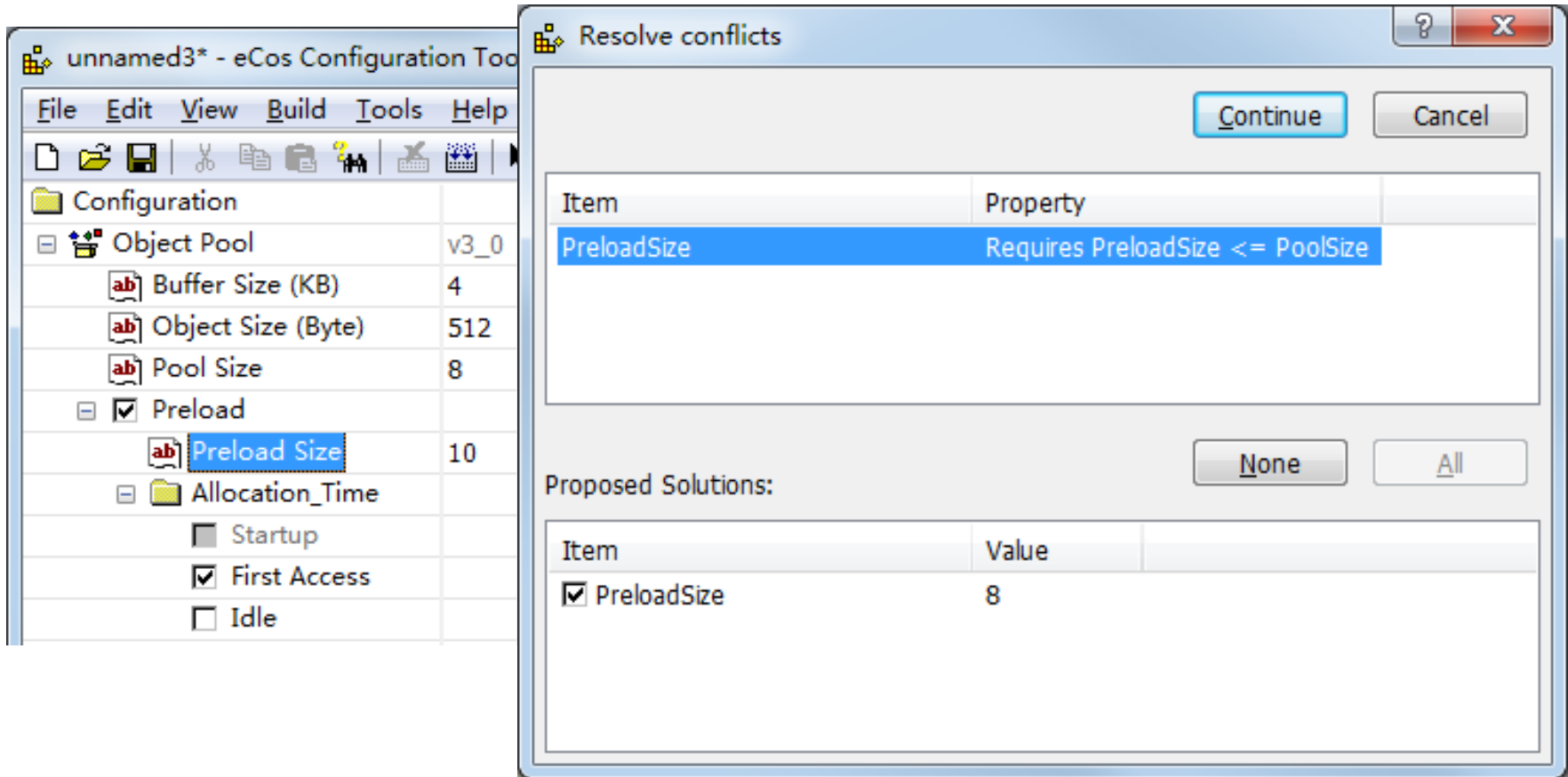
A red callout box with a speech bubble points to the "Startup" option in the tree view, containing the text "disabled".

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

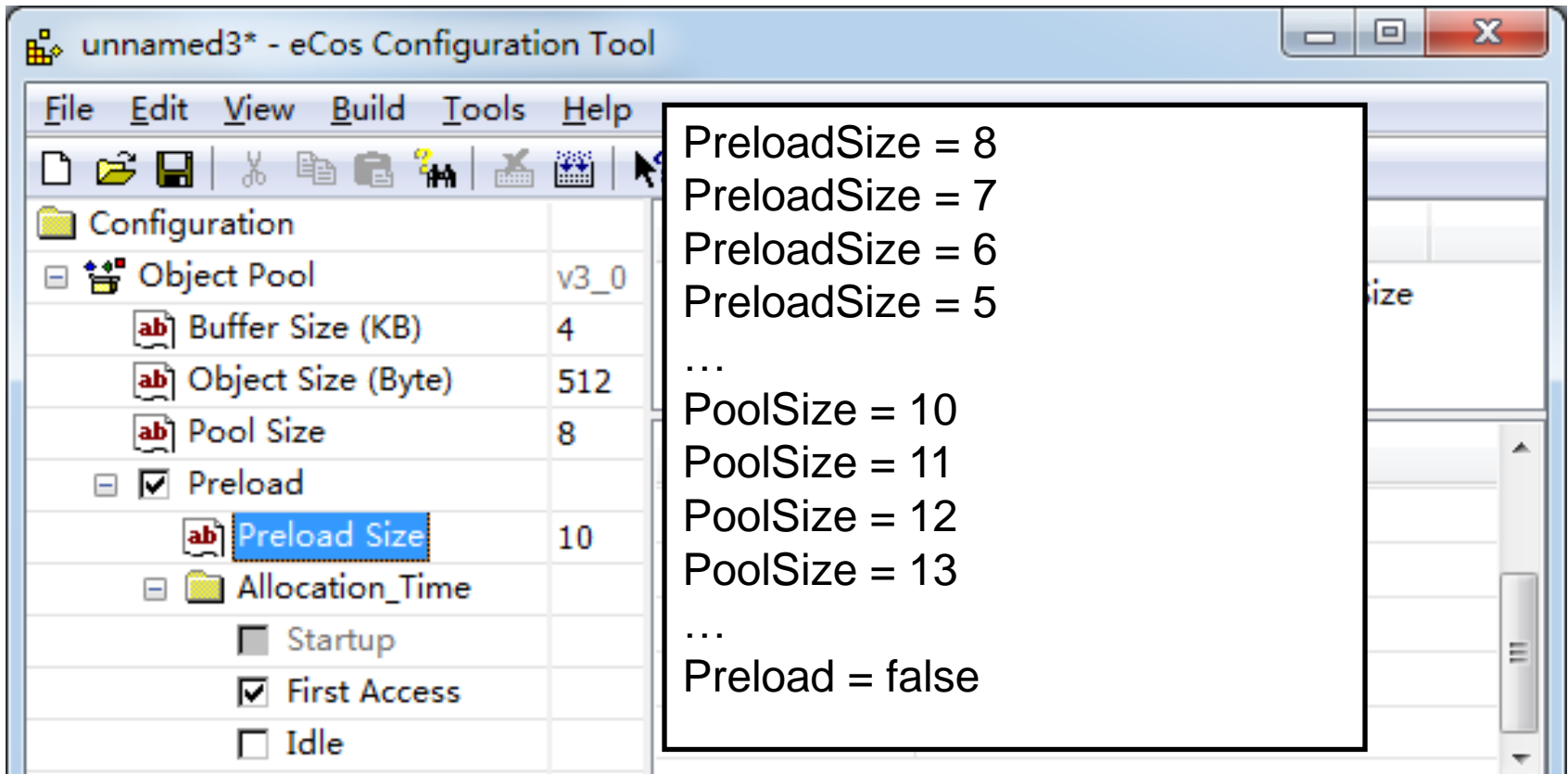
The image shows two windows from the eCos Configuration Tool. The left window, titled 'unnamed3* - eCos Configuration Tool', displays a configuration tree. Under 'Object Pool', the 'Preload Size' is set to 10, and 'Pool Size' is set to 8. A red circle highlights the 'Preload Size' value, and another red circle highlights the 'Pool Size' value. A red box labeled 'Disable' has a line pointing to the 'Preload' checkbox. The right window, titled 'Resolve conflicts', shows a conflict between 'PreloadSize' and 'PoolSize'. The conflict message is 'Requires PreloadSize <= PoolSize'. A red box above the dialog says 'Increase to any value >= 10'. Below the dialog, the 'Proposed Solutions' table shows 'PreloadSize' with a value of 8, which is circled in red. A red box below the dialog says 'Further decrease to any value <= 8'.

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

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

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 for 'unnamed3*'. The configuration table on the left lists various settings, with 'Preload Size' highlighted in blue. A text box on the right lists a series of fixes for the configuration.

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"/>

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]

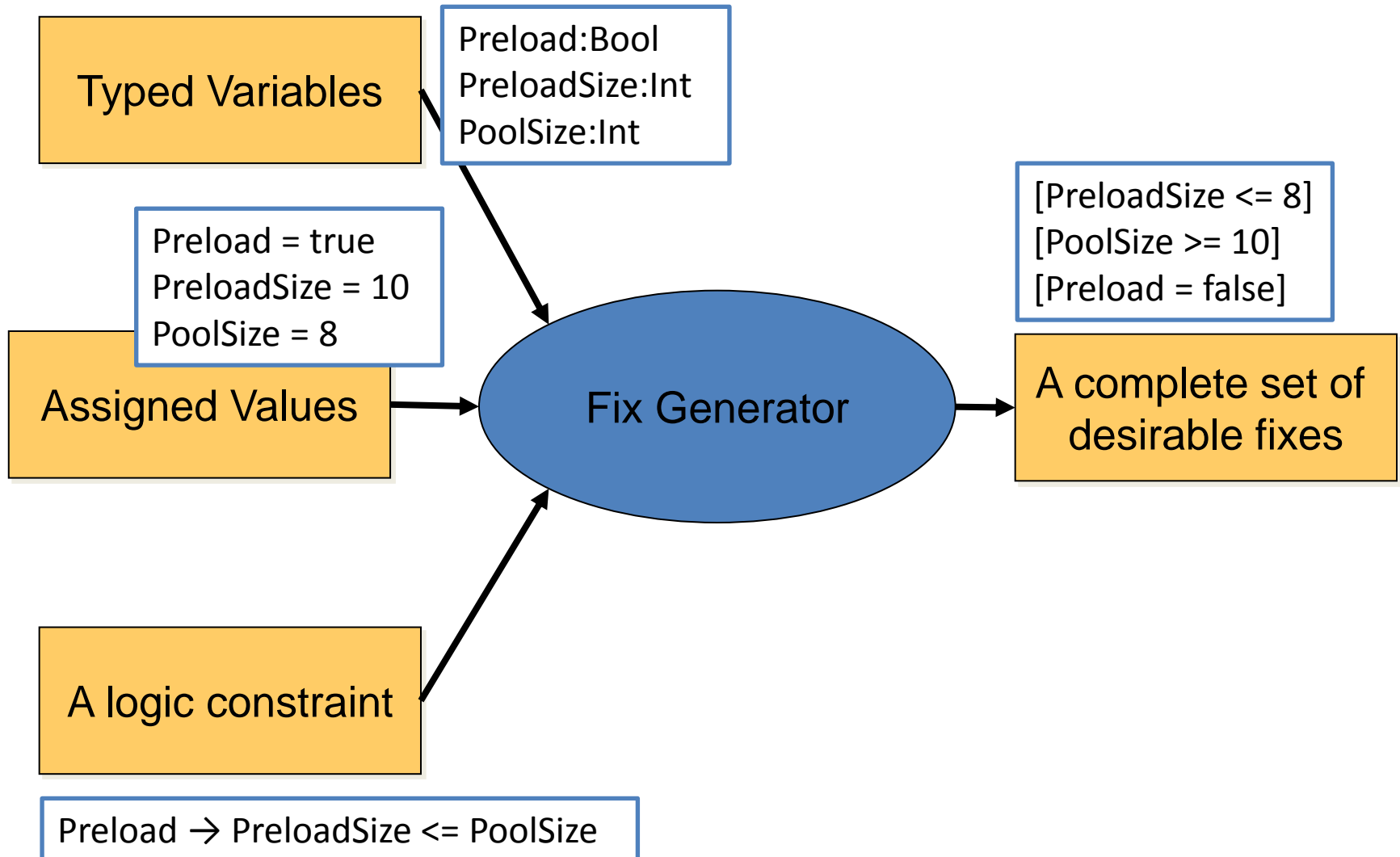
Item	Property
PreloadSize	Requires PreloadSize <= PoolSize
Flavor	data
Requires	PreloadSize <= PoolSize
DefaultValue	10

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 overlaid on the 'Preload Size' row contains 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

Causing another error

Increase PoolSize

Interacting constraint

Item	Property
PoolSize	Requires PoolSize == BufferSize * 1024 / ObjectSize

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

Configuration

- Object Pool (v3_0)
 - Buffer Size (KB): 4
 - Object Size (Byte): 512
 - Pool Size: 12
- Preload (checked)
 - Preload Size: 10
- Allocation_Time
 - Startup:
 - First Access:
 - Idle:

Ignorance

Ignore the interaction

The screenshot shows the 'eCos Configuration Tool' window for 'unnamed3*'. The 'Configuration' tree on the left lists the following items and values:

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 overlaid on the 'Preload Size' value contains the following text:

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


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"/>

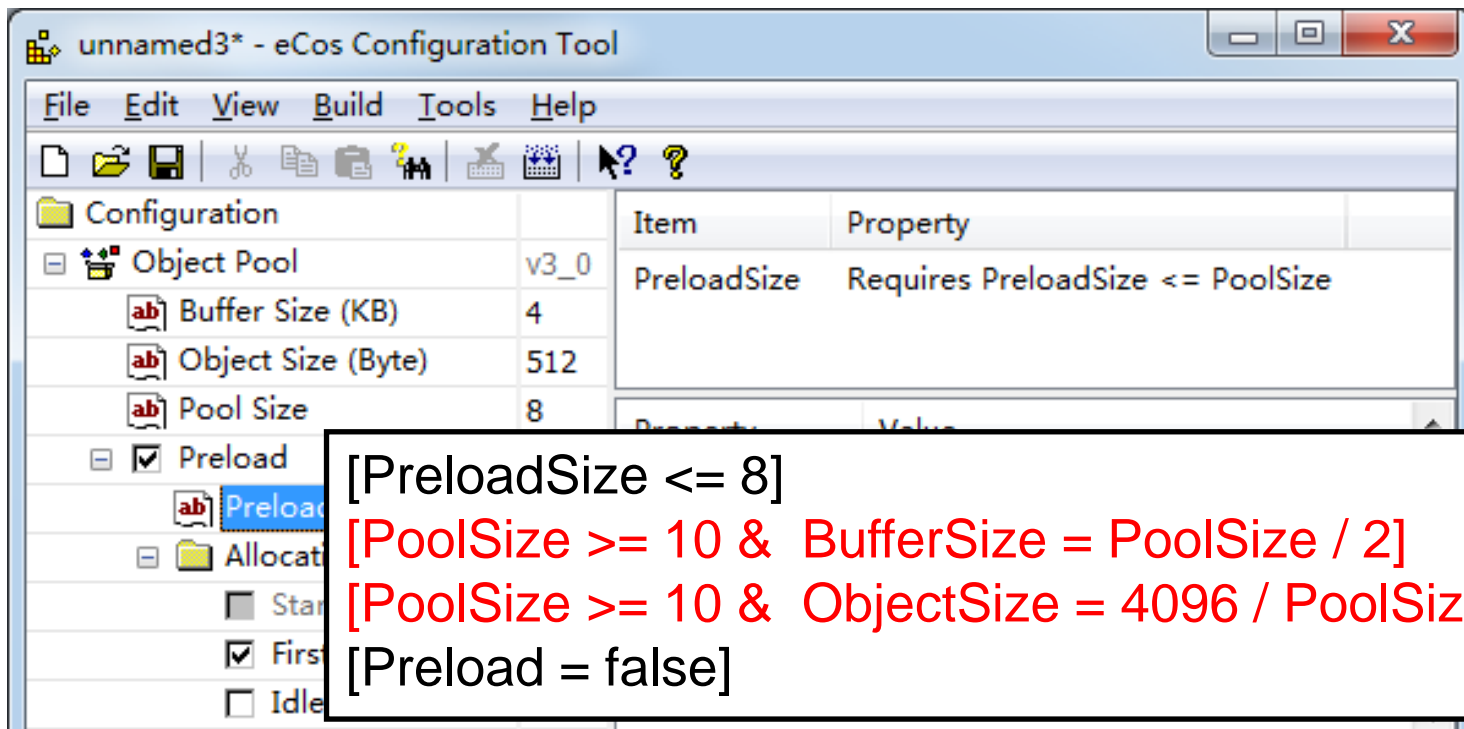
A callout box highlights the following constraints:

- [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 'First Access' checkbox is checked. The 'Startup' and 'Idle' checkboxes are unchecked.

Propagation

Propagate the change along other constraints



The screenshot shows the 'eCos Configuration Tool' window. The 'Configuration' tree on the left is expanded to show the 'Object Pool' configuration. The 'Preload' checkbox is checked. A callout box contains the following constraints:

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

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

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>