Range Fixes and Their Application on Software Configuration

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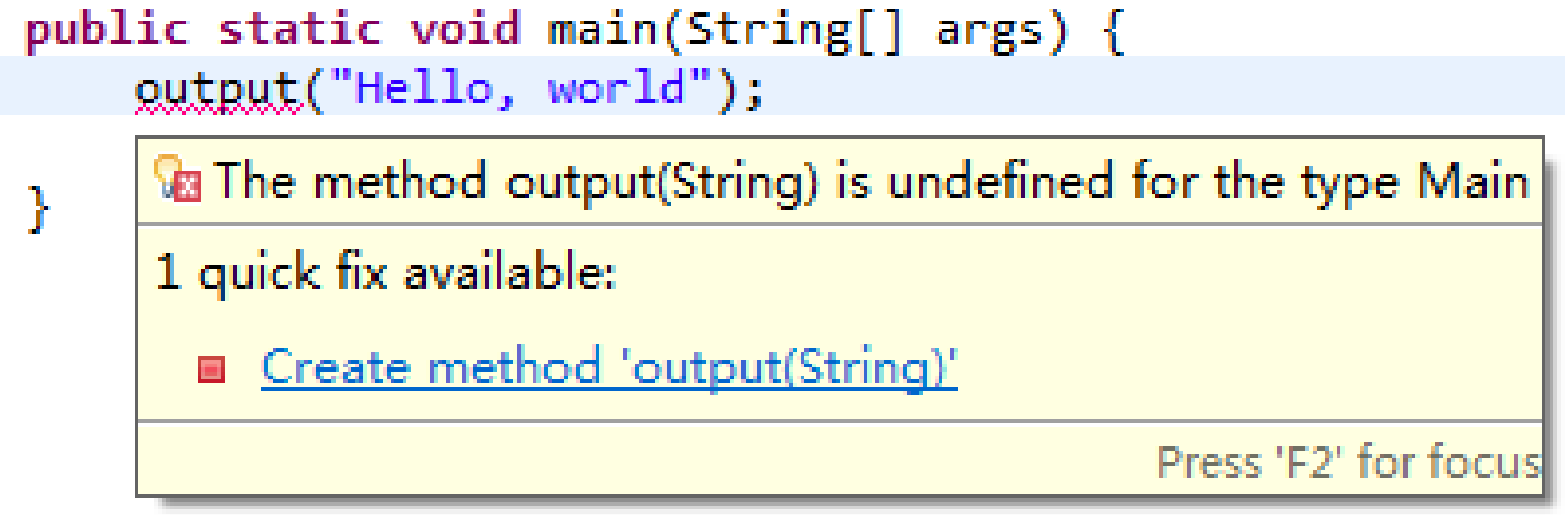
Based on an ICSE'12 paper with
Arnaud Hubaux (U. Namur),
Steven She and Krzysztof Czarnekci (U. Waterloo)

We produce errors everyday



```
public static void main(String[] args) {
    output("Hello, world");

}
```

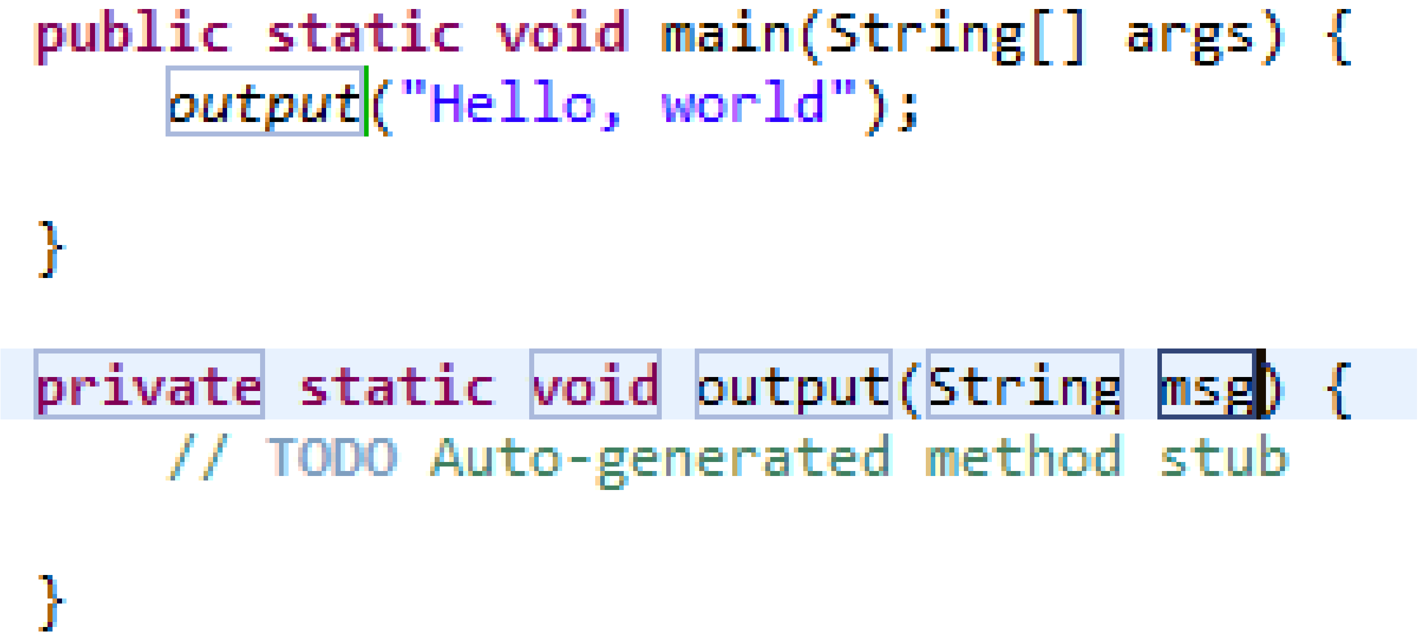
The method output(String) is undefined for the type Main

1 quick fix available:

Create method 'output(String)'

Press 'F2' for focus

We use fixes everyday



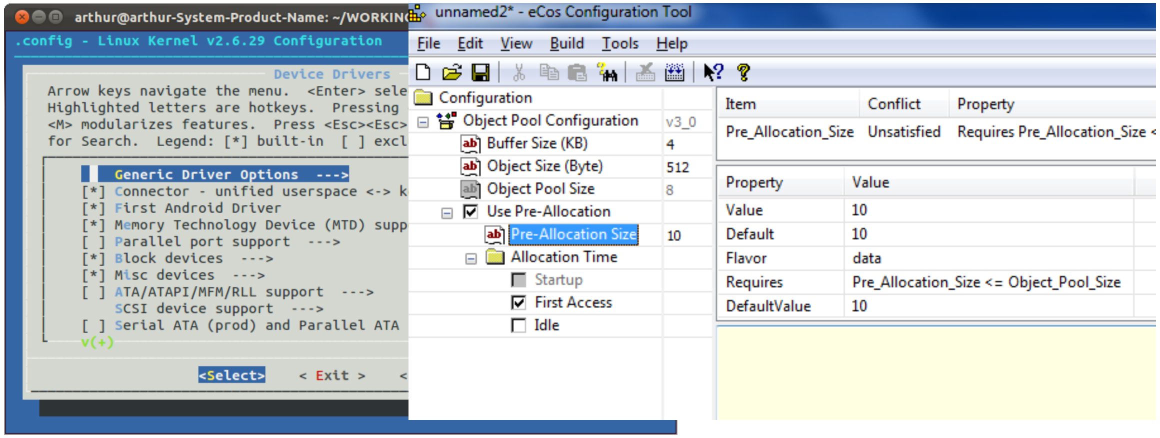
```
public static void main(String[] args) {
    output("Hello, world");

}

private static void output(String msg) {
    // TODO Auto-generated method stub

}
```

How much do we know about fixes?

- How much are fixes needed?
- What fixes are desirable?
- Can we generate fixes automatically?

Study domain: operating system configuration

Configuration



```
arthur@arthur-System-Product-Name: ~/WORKIN
.config - Linux Kernel v2.6.29 Configuration
                                        Device Drivers
  Arrow keys navigate the menu.  <Enter> sele
  Highlighted letters are hotkeys.  Pressing
  <M> modularizes features.  Press <Esc><Esc>
  for Search.  Legend: [*] built-in  [ ] excl

        Generic Driver Options  --->
    [*] Connector - unified userspace <-> k
    [*] First Android Driver
    [*] Memory Technology Device (MTD) supp
    [ ] Parallel port support  --->
    [*] Block devices  --->
    [*] Misc devices  --->
    [ ] ATA/ATAPI/MFM/RLL support  --->
        SCSI device support  --->
    [ ] Serial ATA (prod) and Parallel ATA
    v(+)

              <Select>    < Exit >    <
```

unnamed2* - eCos Configuration Tool

```
Configuration
⊟ Object Pool Configuration        v3_0
      Buffer Size (KB)             4
      Object Size (Byte)           512
      Object Pool Size             8
  ⊟ ☑ Use Pre-Allocation
        Pre-Allocation Size        10
    ⊟ Allocation Time
        □ Startup
        ☑ First Access
        □ Idle
```

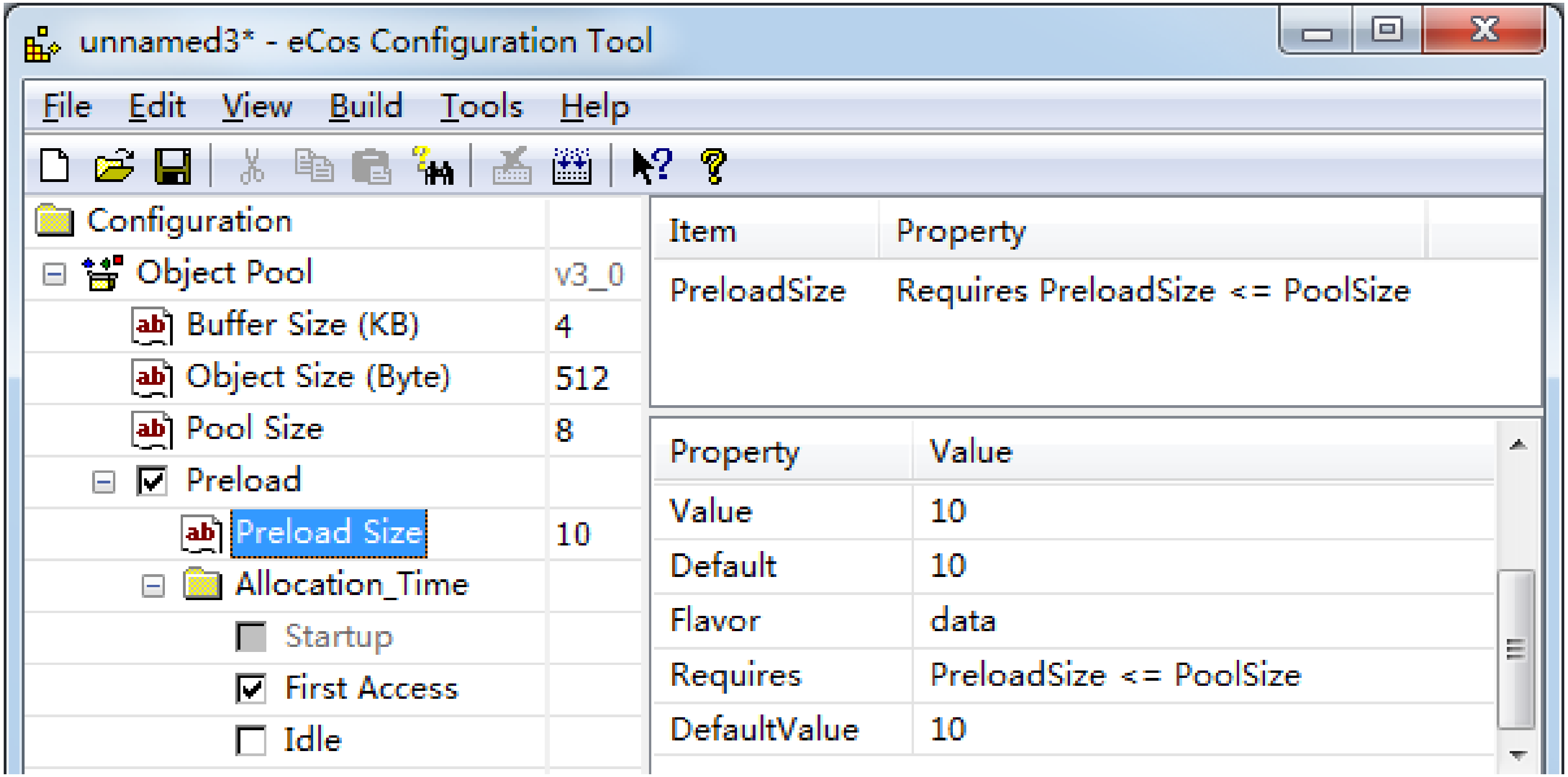
Item	Conflict	Property
Pre_Allocation_Size	Unsatisfied	Requires Pre_Allocation_Size <

Property	Value
Value	10
Default	10
Flavor	data
Requires	Pre_Allocation_Size <= Object_Pool_Size
DefaultValue	10

Linux Kconfig,
eCos CDL,
…

Variability Models

eCos Configurator - Errors



Configuration	
⊟ Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
⊟ ☑ Preload	
Preload Size	10
⊟ Allocation_Time	
☐ Startup	
☑ First Access	
☐ Idle	

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

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

Contributions

- How much are fixes needed?
  - A survey revealing manual fixes take minutes
- What fixes are desirable?
  - A new type of fix, range fix, and evaluated desirable properties of fixes
- Can we generate fixes automatically?
  - An algorithm generating range fixes in tens of milliseconds

How much are fixes needed?

A survey showing manual fixes take minutes

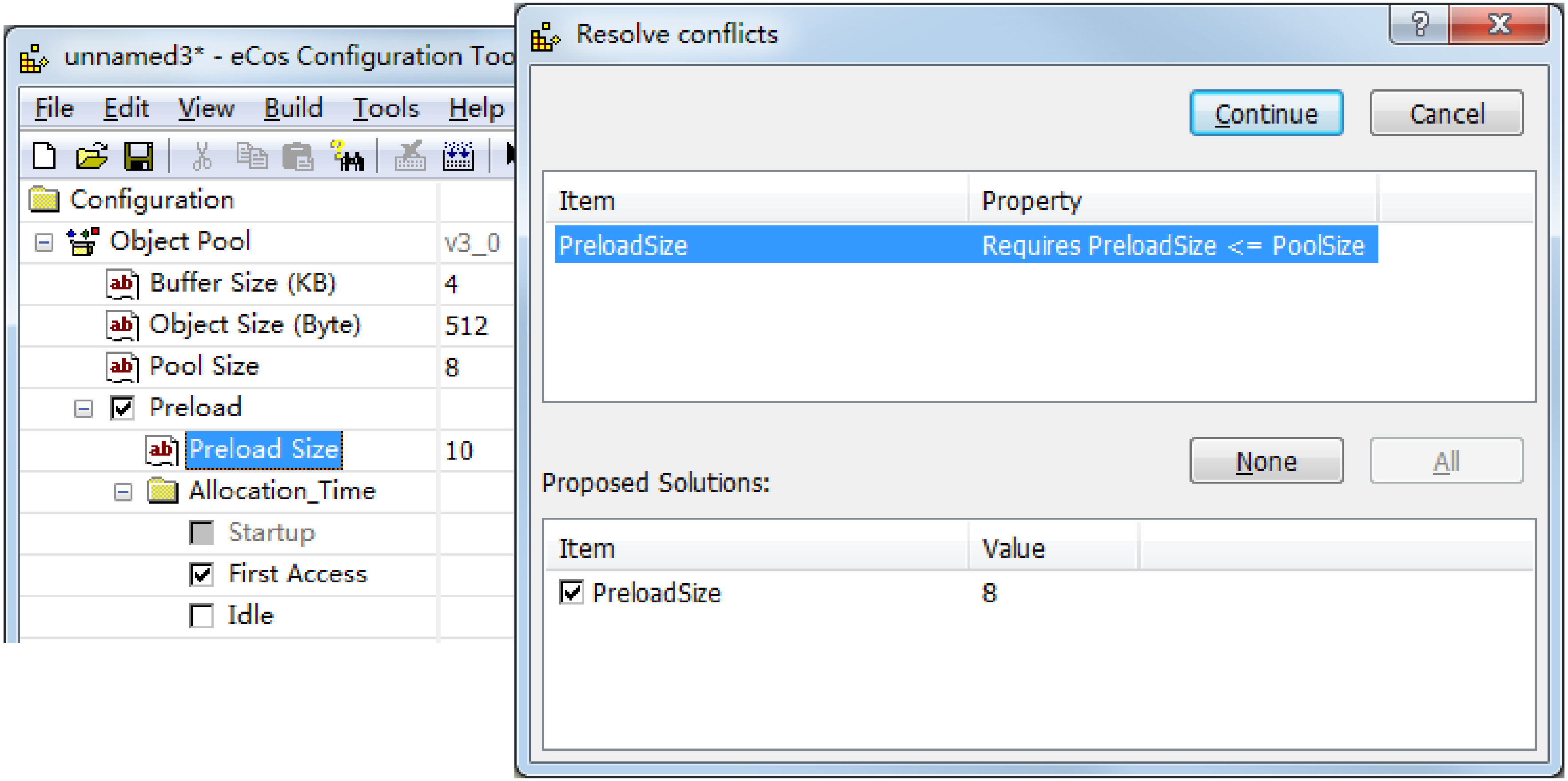
Survey

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

What fixes are desirable?

A new type of fixes, range fixes, and evaluated desirable properties

eCos Configurator



Configuration

- ⊟ Object Pool — v3_0
  - Buffer Size (KB) — 4
  - Object Size (Byte) — 512
  - Pool Size — 8
  - ⊟ ☑ Preload
    - Preload Size — 10
    - ⊟ Allocation_Time
      - □ Startup
      - ☑ First Access
      - □ Idle

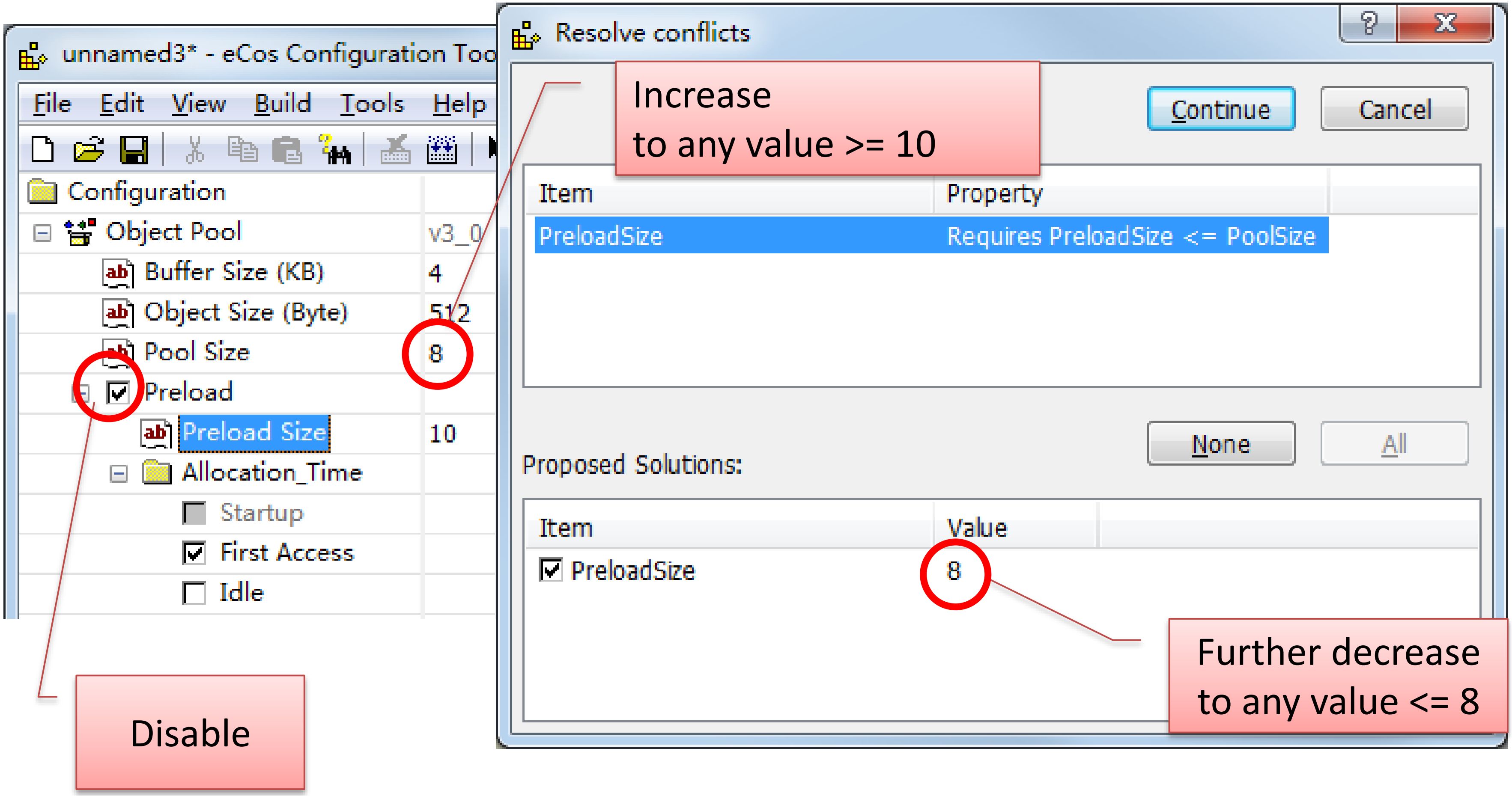
Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

Proposed Solutions:

Item	Value
☑ PreloadSize	8

eCos configurator has built-in fixes

Fix Incompleteness


unnamed3* - eCos Configuration Too
File Edit View Build Tools Help
Resolve conflicts
Continue
Cancel
None
All

Configuration
⊟ Object Pool v3_0
Buffer Size (KB) 4
Object Size (Byte) 512
Pool Size 8
☑ Preload
Preload Size 10
⊟ Allocation_Time
□ Startup
☑ First Access
□ Idle

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

Proposed Solutions:

Item	Value
☑ PreloadSize	8

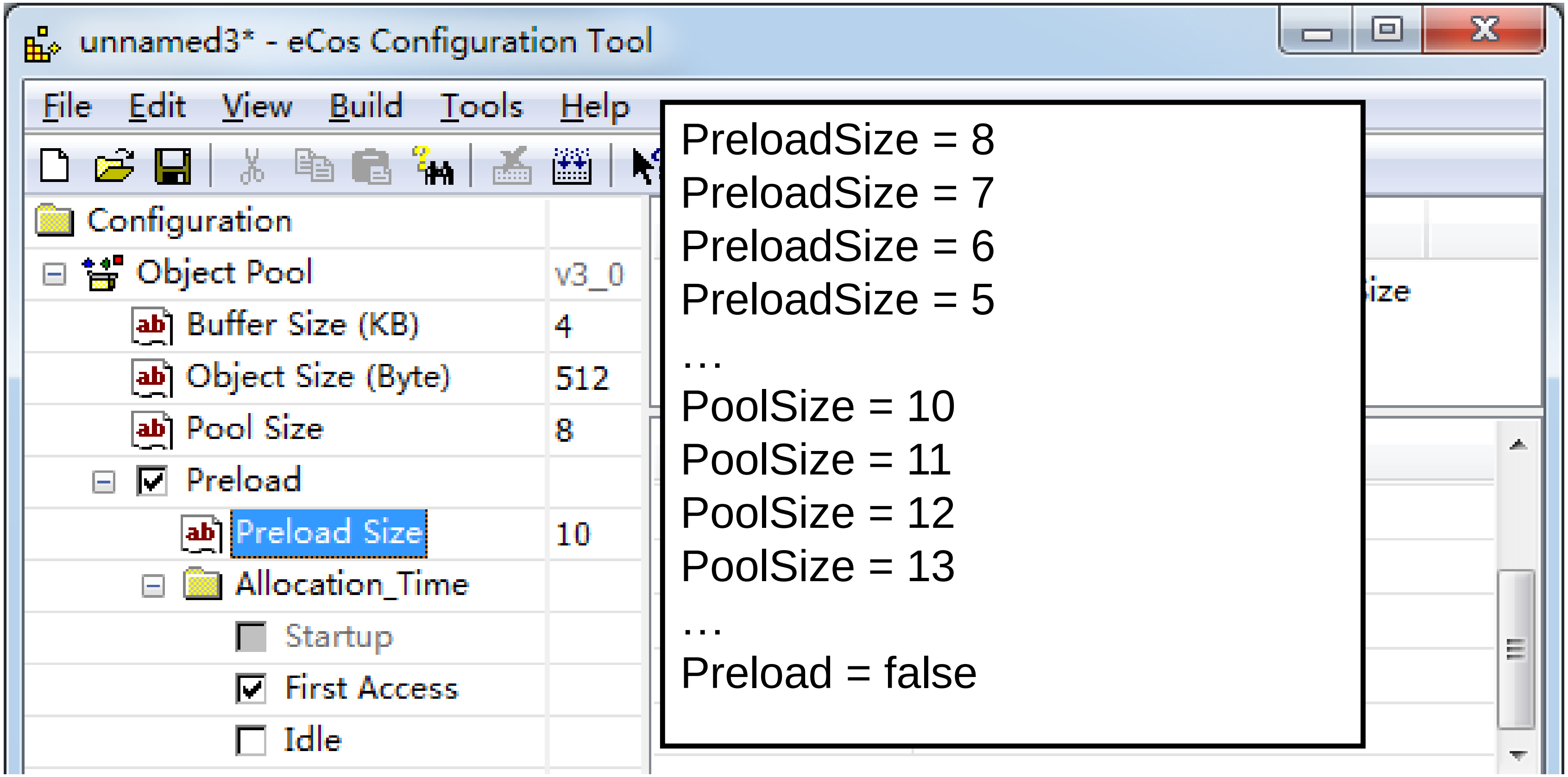
Increase
to any value >= 10

Disable

Further decrease
to any value <= 8

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

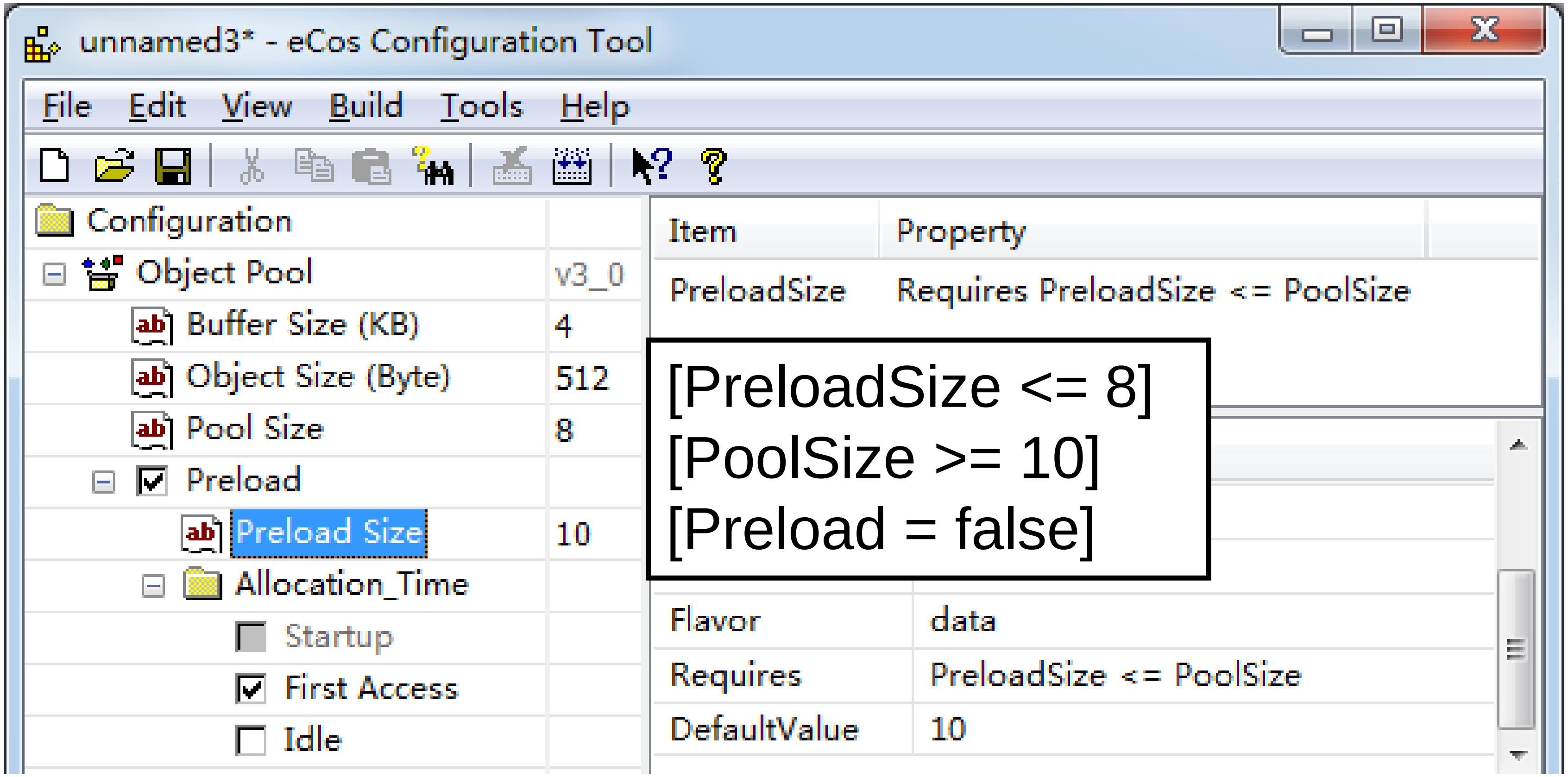
How to complete fixes


unnamed3* - eCos Configuration Tool
File Edit View Build Tools Help

Configuration
⊟ Object Pool v3_0
Buffer Size (KB) 4
Object Size (Byte) 512
Pool Size 8
⊟ ☑ Preload
Preload Size 10
⊟ Allocation_Time
□ Startup
☑ First Access
□ Idle

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

Our Proposal – Range Fixes



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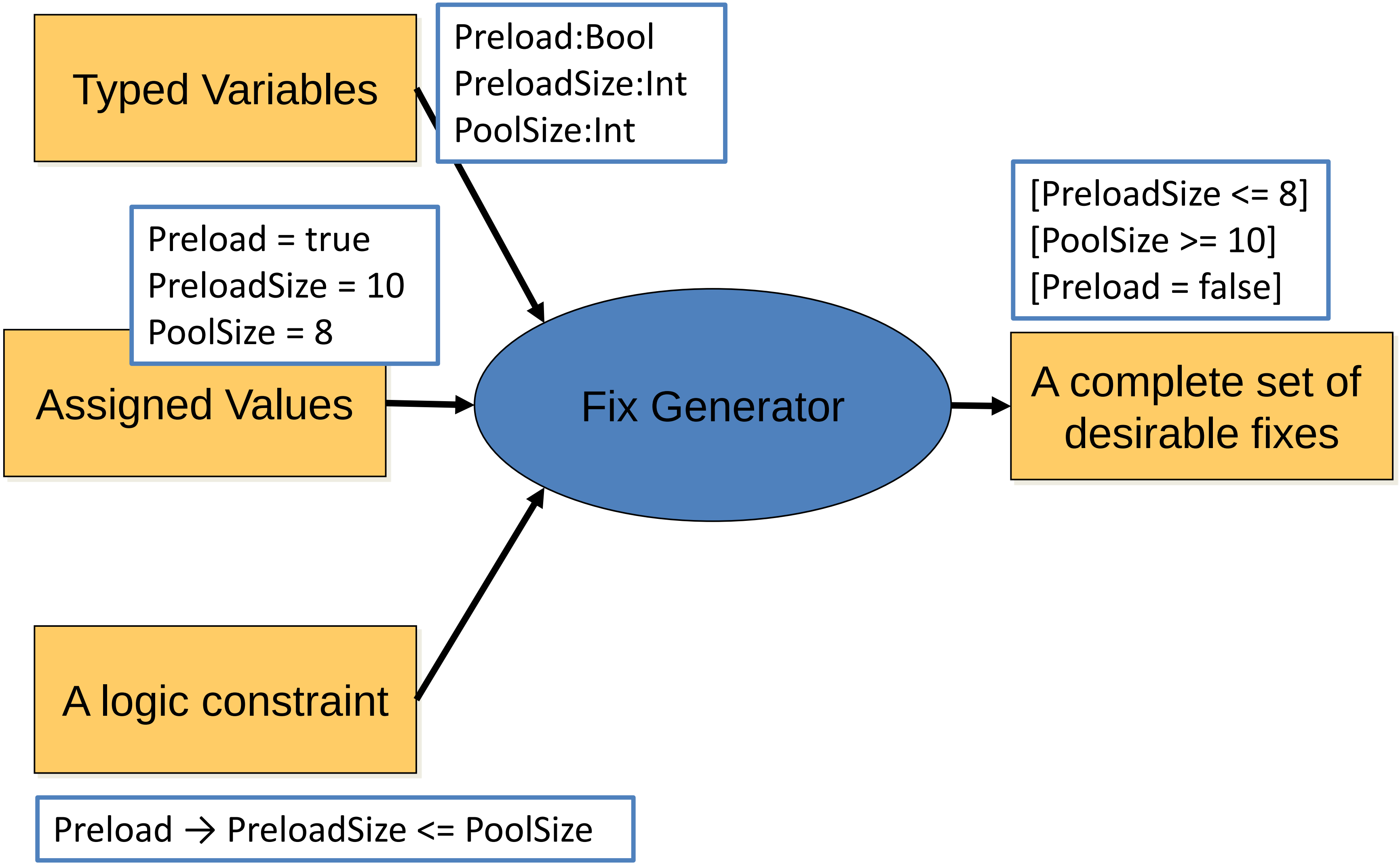
⊟ Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
⊟ ☑ Preload	
Preload Size	10
⊟ Allocation_Time	
□ Startup	
☑ First Access	
□ Idle	

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

Flavor	data
Requires	PreloadSize <= PoolSize
DefaultValue	10

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

Fix Generation Problem – a General Definition



Typed Variables

Preload:Bool
PreloadSize:Int
PoolSize:Int

Assigned Values

Preload = true
PreloadSize = 10
PoolSize = 8

A logic constraint

Preload → PreloadSize <= PoolSize

Fix Generator

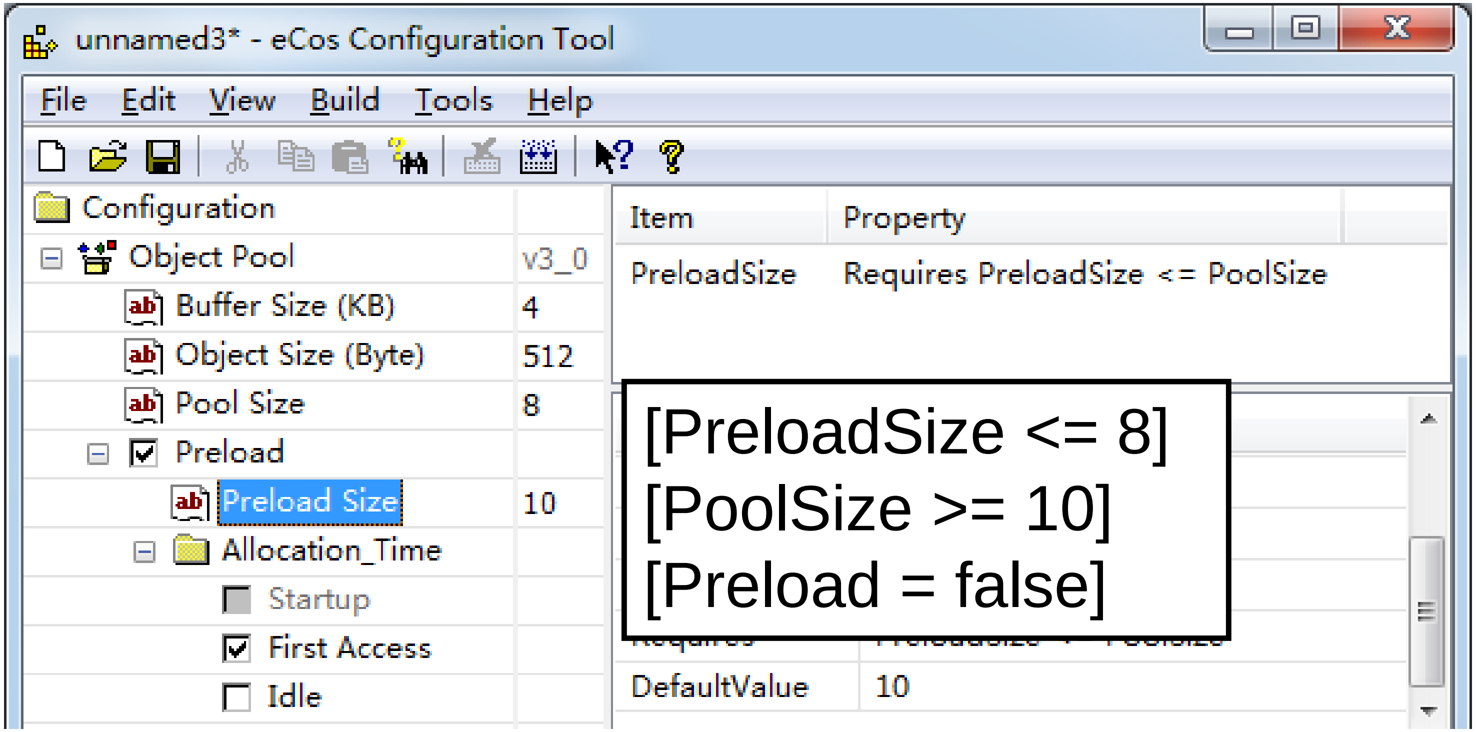
A complete set of desirable fixes

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

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]

Constraint Interaction



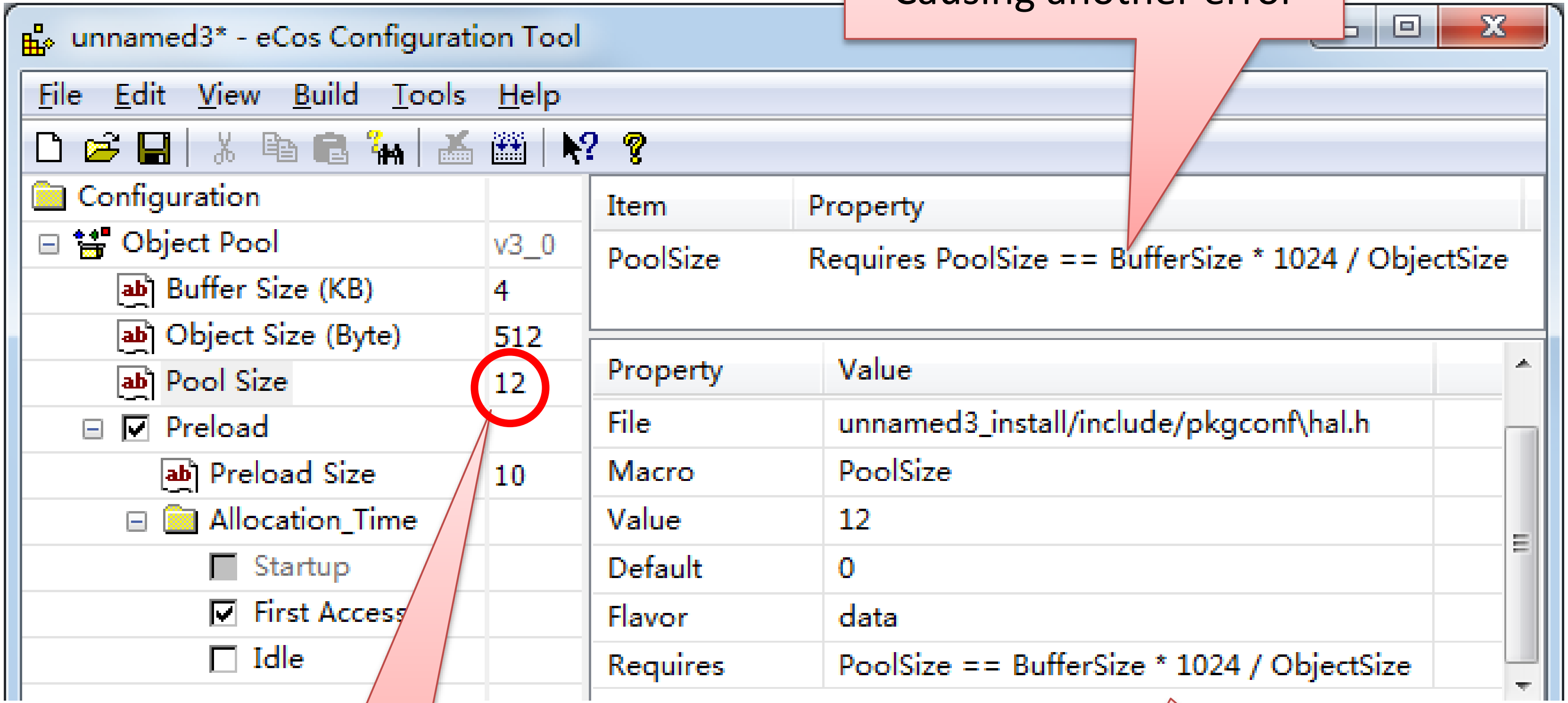
Configuration	
⊟ Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
⊟ ☑ Preload	
Preload Size	10
⊟ Allocation_Time	
■ Startup	
☑ First Access	
□ Idle	

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

Requires	PreloadSize <= PoolSize
DefaultValue	10

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

Constraint Interaction



Configuration	
⊟ Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	12
⊟ ☑ Preload	
Preload Size	10
⊟ Allocation_Time	
□ Startup	
☑ First Access	
□ Idle	

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

Causing another error

Increase PoolSize

Interacting constraint

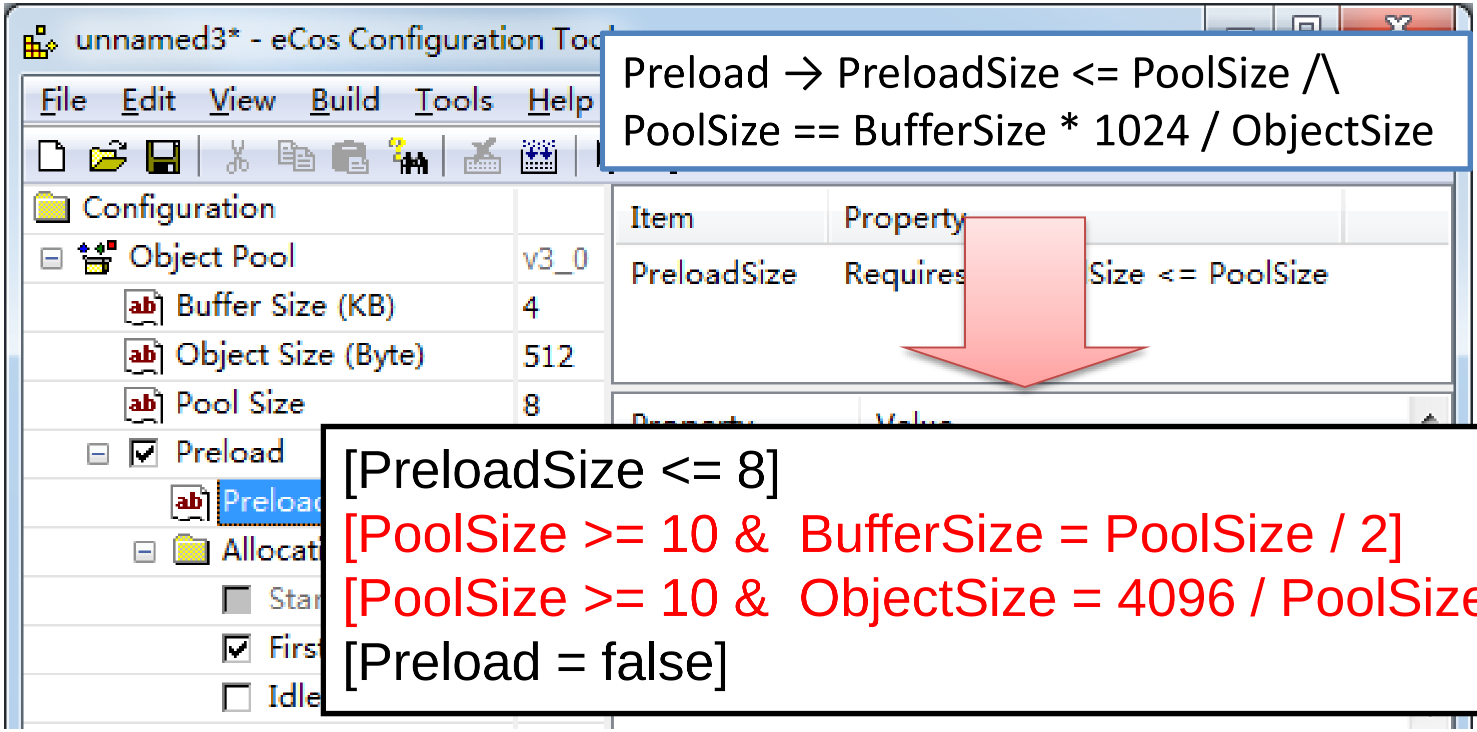
Three Strategies

- Ignorance
- Elimination
- Propagation

- Summarized from existing approaches

Propagation Strategy

Make a conjunction of all satisfied constraints plus the violated one


unnamed3* - eCos Configuration Too
File Edit View Build Tools Help

Configuration	
⊟ Object Pool	v3_0
Buffer Size (KB)	4
Object Size (Byte)	512
Pool Size	8
⊟ ☑ Preload	
Preloa	
⊟ Allocati	
□ Star	
☑ Firs	
□ Idle	

Item	Property	
PreloadSize	Requires	Size <= PoolSize

Preload → PreloadSize <= PoolSize /\
PoolSize == BufferSize * 1024 / ObjectSize

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

Evaluation

- 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

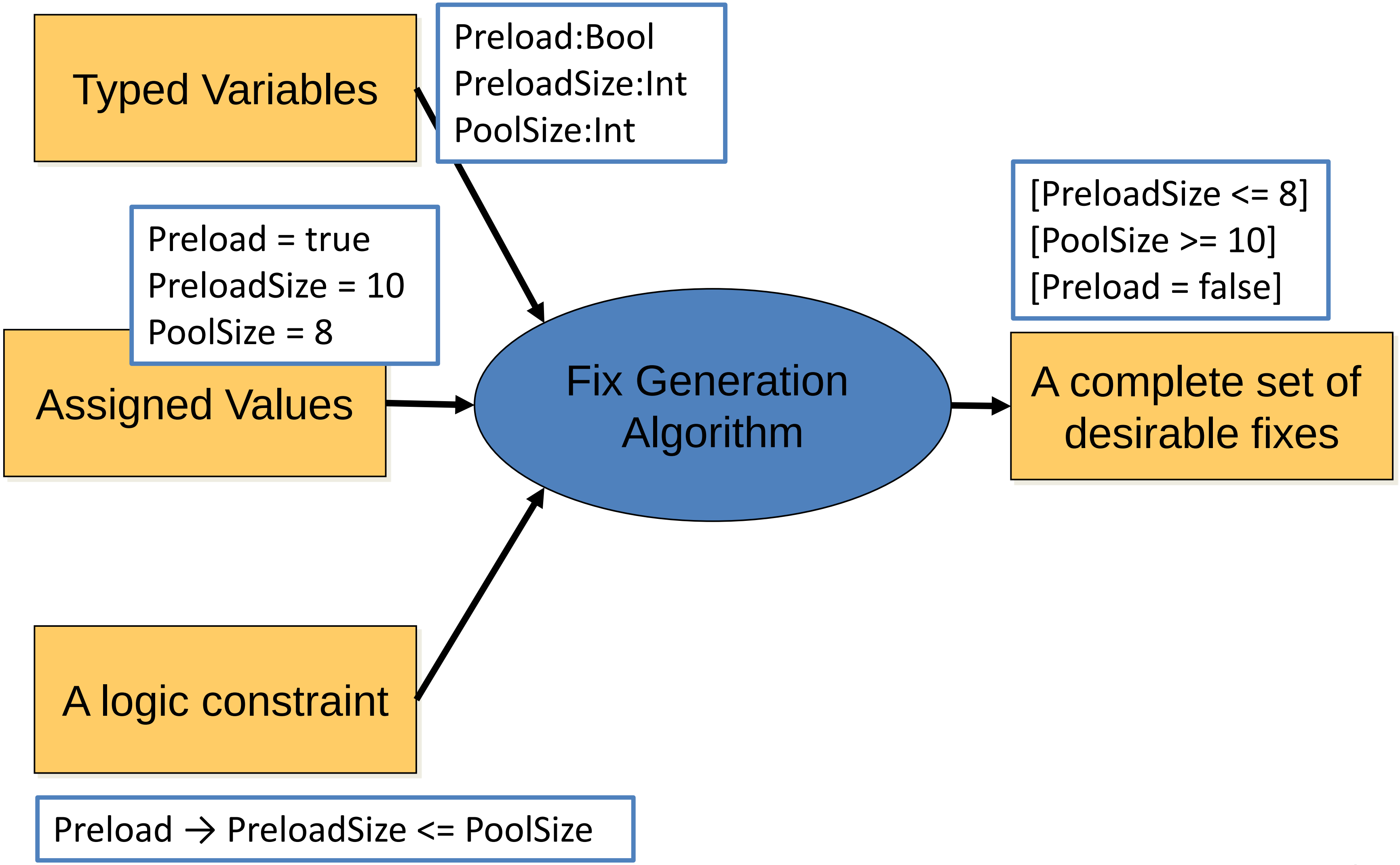
Results

- Coverage of User changes: 100%
- Complexity of fix lists
  - measured by adding up the number of variables in each fix
  - Median: 2
  - Maximum: 58
  - 83% of the fix lists contain less than 10 variables

Can we generate fixes automatically?

An algorithm generating range fixes
in tens of milliseconds

Interface of our algorithm



Typed Variables

Preload:Bool
PreloadSize:Int
PoolSize:Int

Preload = true
PreloadSize = 10
PoolSize = 8

Assigned Values

Fix Generation Algorithm

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

A complete set of desirable fixes

A logic constraint

Preload → PreloadSize <= PoolSize

Algorithm Outline

- Step 1: find the variables to change
  - Basic idea: translating to an SMT proble
    1. treat configurations also as constraints
    2. ask an SMT solver for unsatisfiable cores
    3. combine the unsatisfiable cores
- Step 2: find the range of the variables
  - Basic idea: simplify the constraint
    1. replace unchangeable variables with their current values
    2. simplify the constraint and convert to CNF

Performance of the algorithm

- Published results
  - Average: 50ms
  - Maximum: 250ms

- We have recently improved the performance

Thank you for your attention!

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