软件配置的交互式修复

北京大学 熊英飞

合作者

北京大学	王波、张汉生、王杰、赵海燕、张伟
University of Waterloo	Leonardo Passos, Steven She, Krzysztof Czarnecki
University of Namur	Arnaud Hubaux

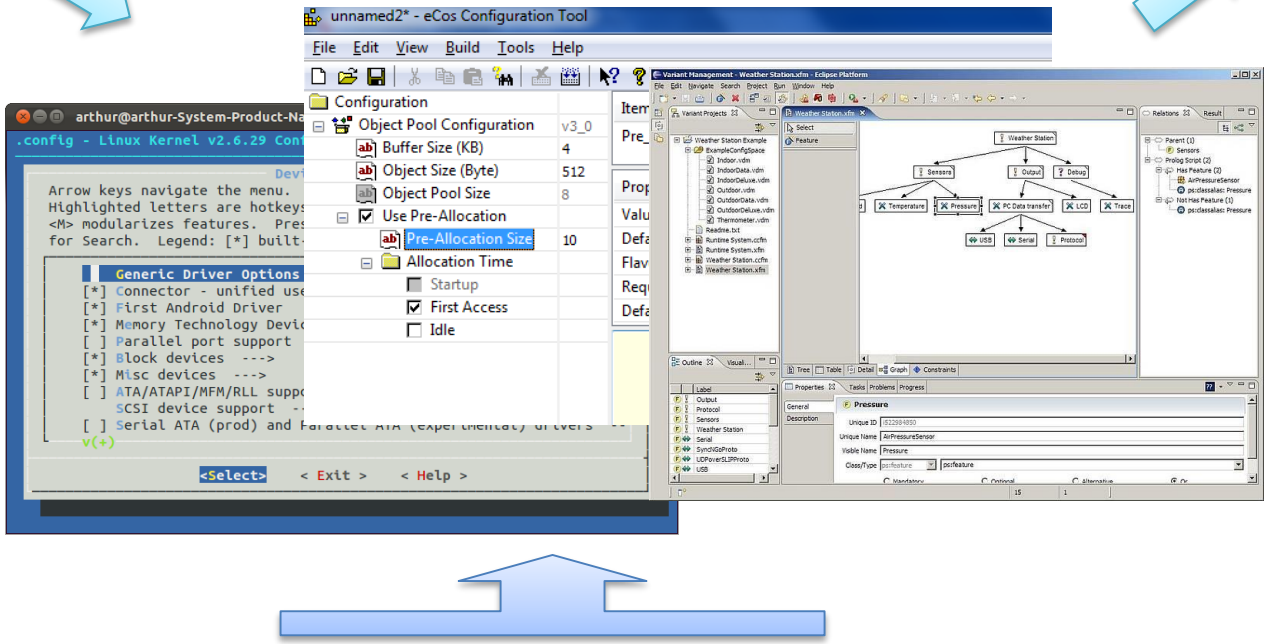
2014 NASAC

报告人介绍 – 熊英飞

- 2000~2004，电子科技大学本科
- 2004~2006，北京大学研究生
  - 导师：梅宏、杨芙清
- 2006~2009，日本东京大学博士
  - 导师：胡振江、武市正人
- 2009~2011，加拿大滑铁卢大学博士后
  - 导师：Krzysztof Czarnecki
- 2012~，北京大学“百人计划”研究员
- 研究方向：软件分析、编程语言设计

Variability Models & Configurators

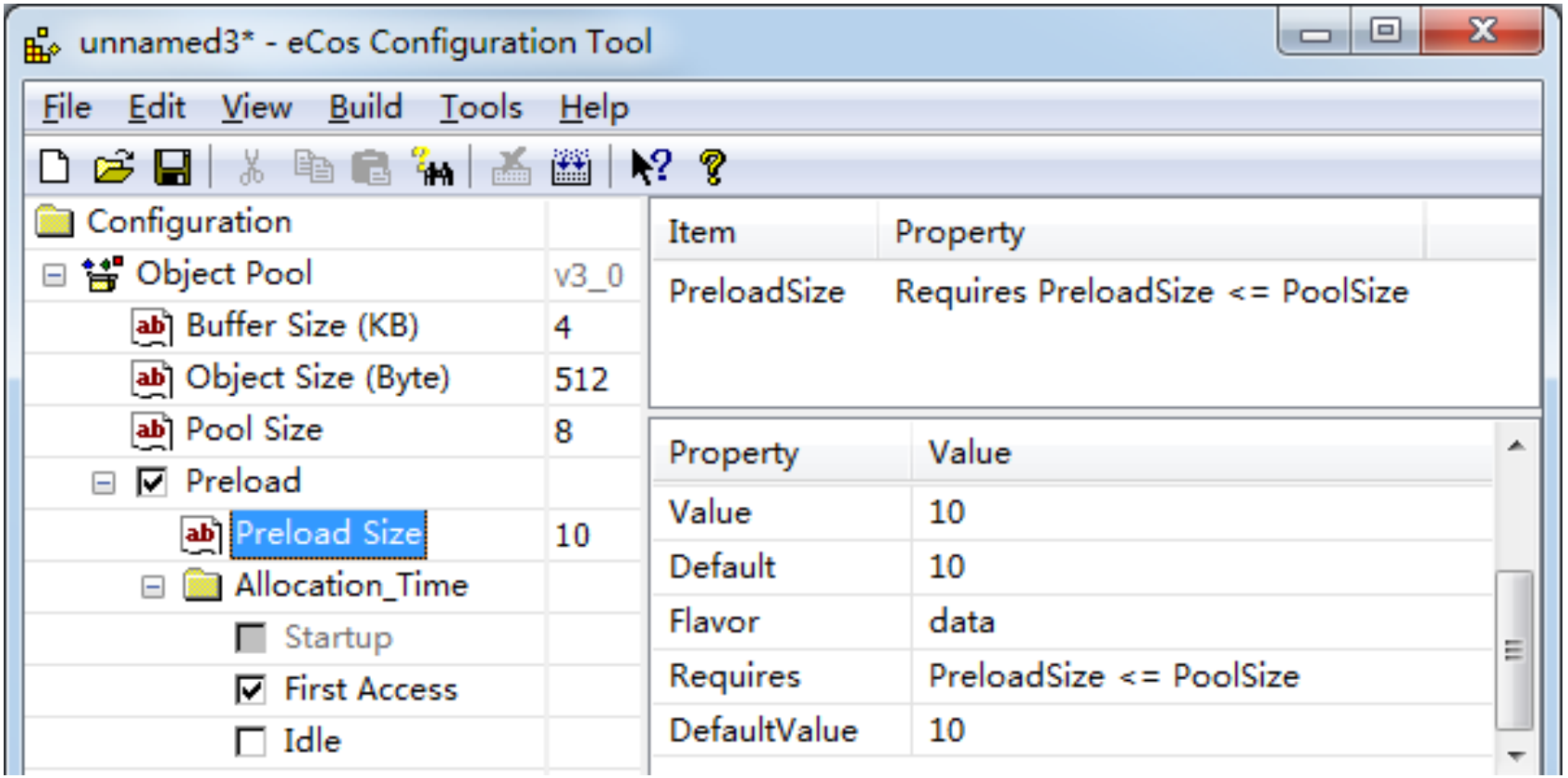
Configuration



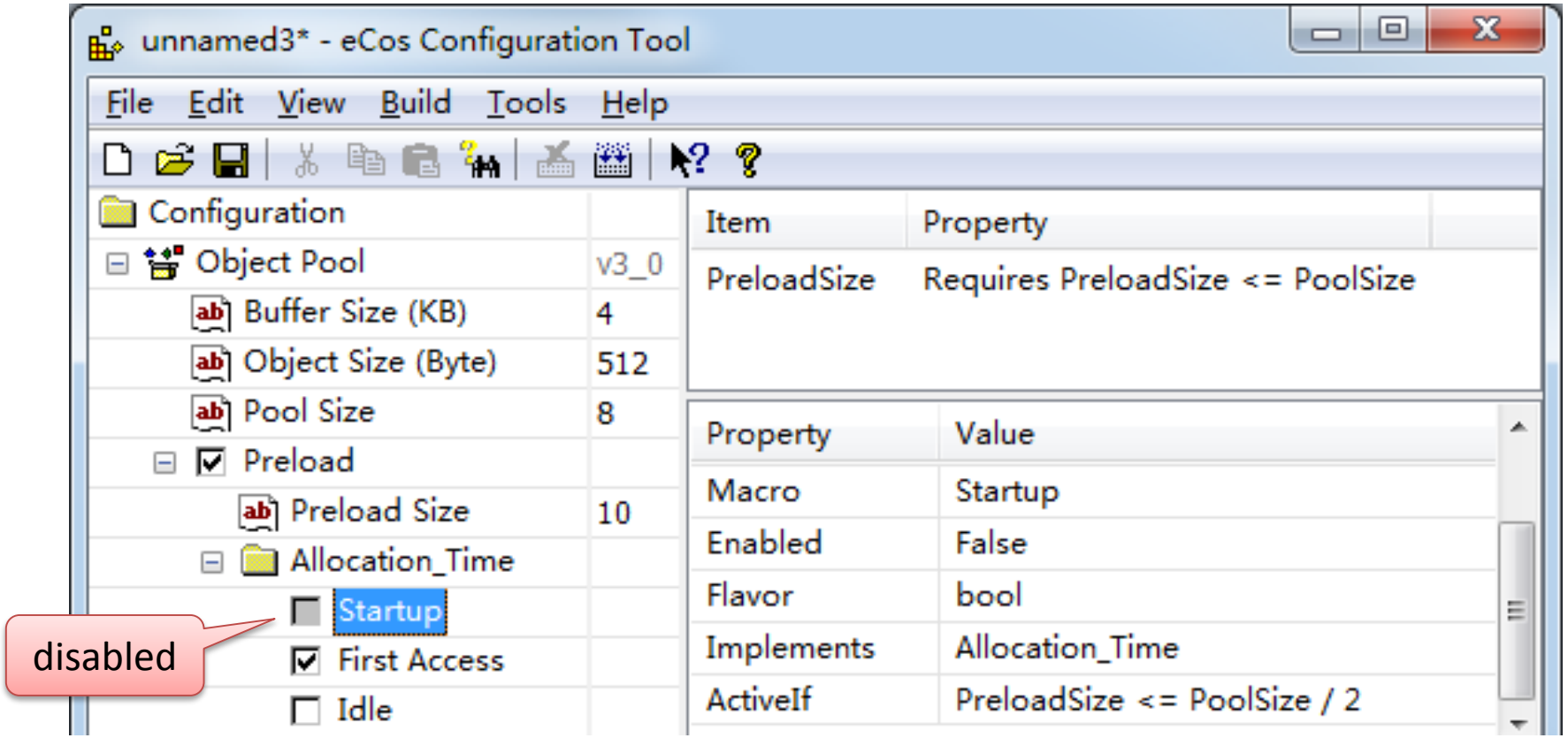
Linux Kconfig,
eCos CDL,
pure::variants,
…

Variability Models

eCos Configurator - Errors



eCos Configurator - Inactive Options

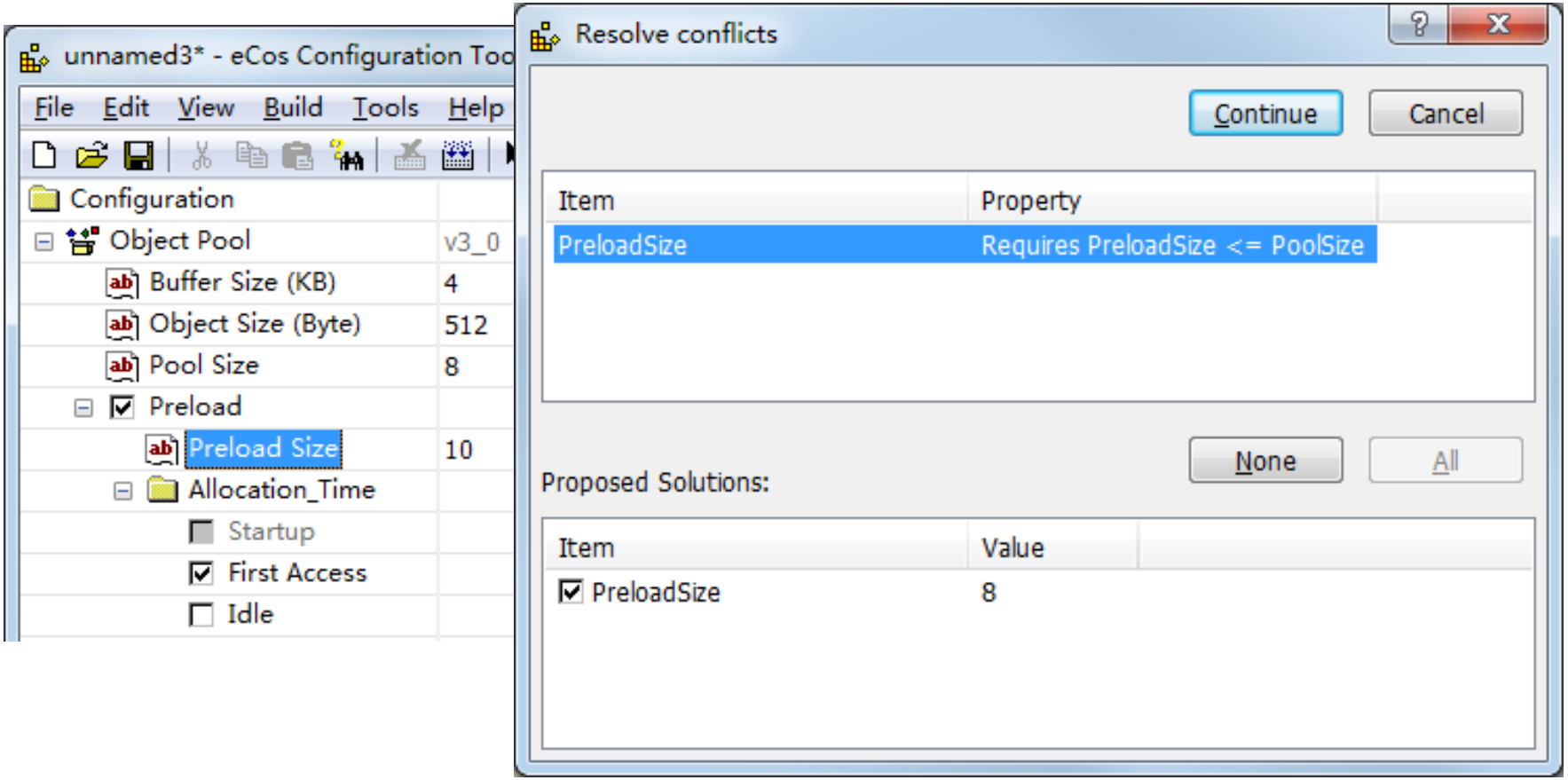


Error resolution and option activation both need to resolve violation of constraint.

Survey

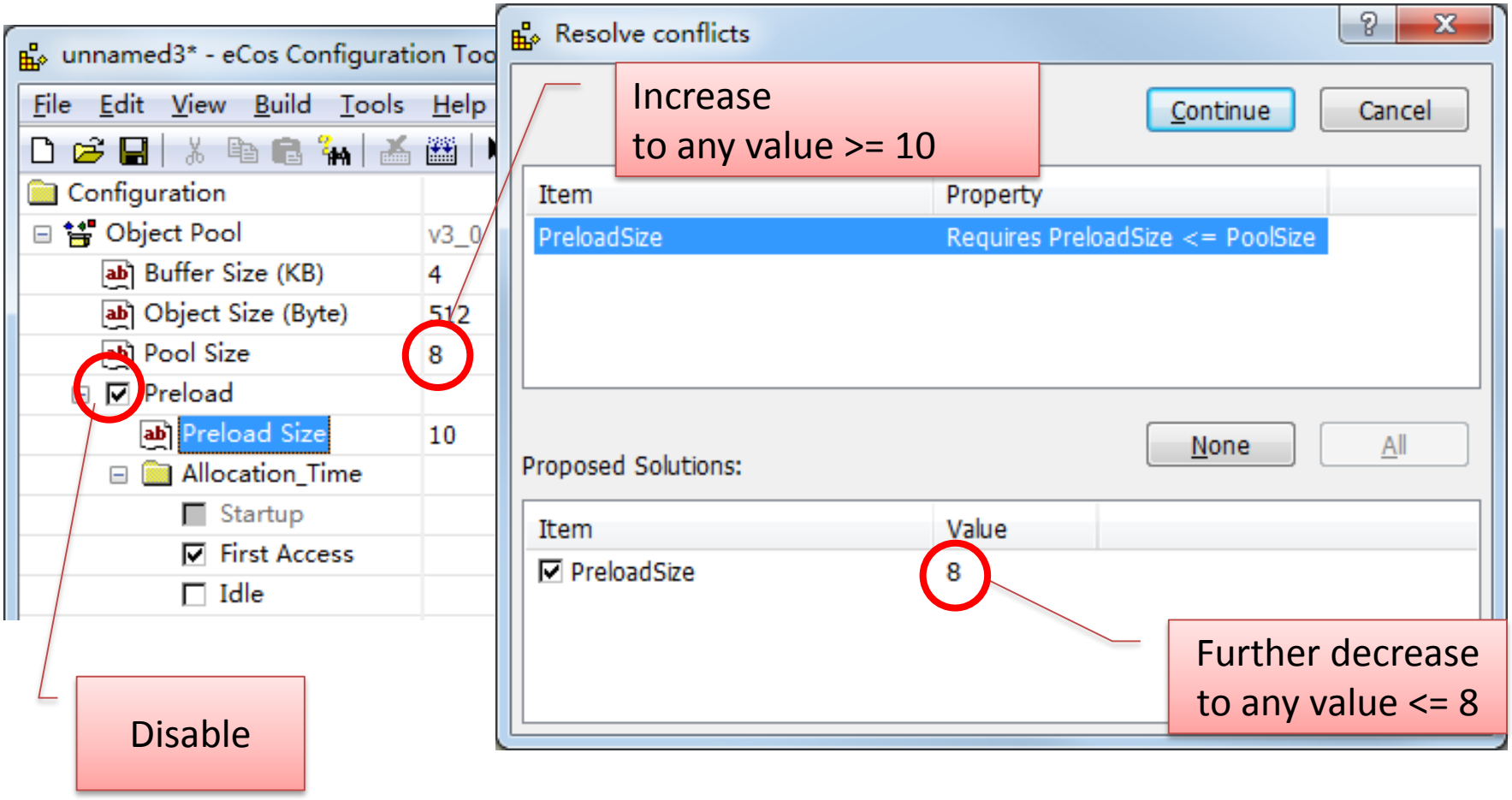
- 97 Linux users and 9 eCos users
- Resolving a violation is hard
  - 20% Linux users need "a few dozen minutes" to activate an option in average
  - 56% eCos users consider activation to be a problem

eCos Configurator



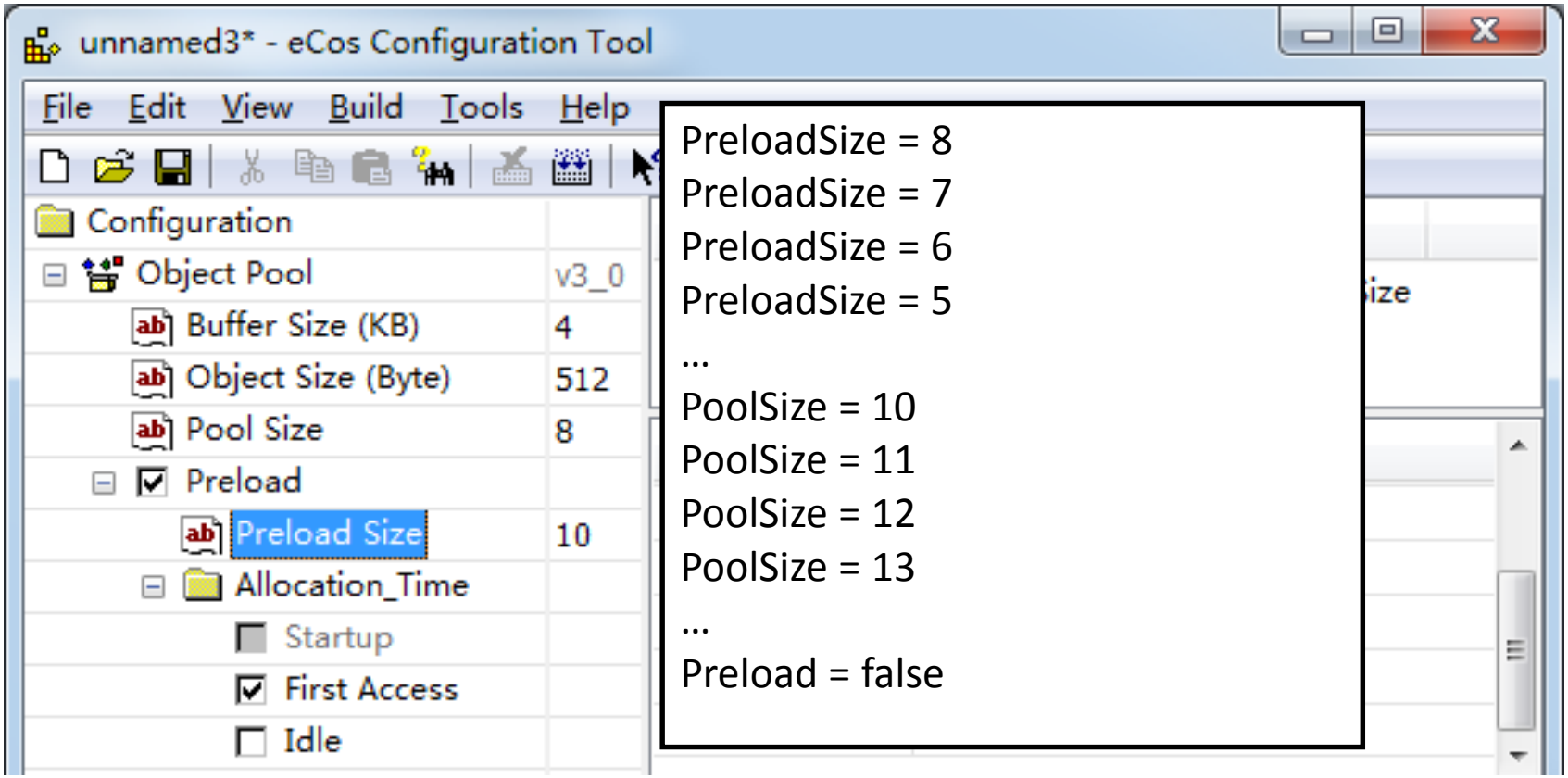
Essentially, fixes work for both resolving errors and activating options

Fix Incompleteness

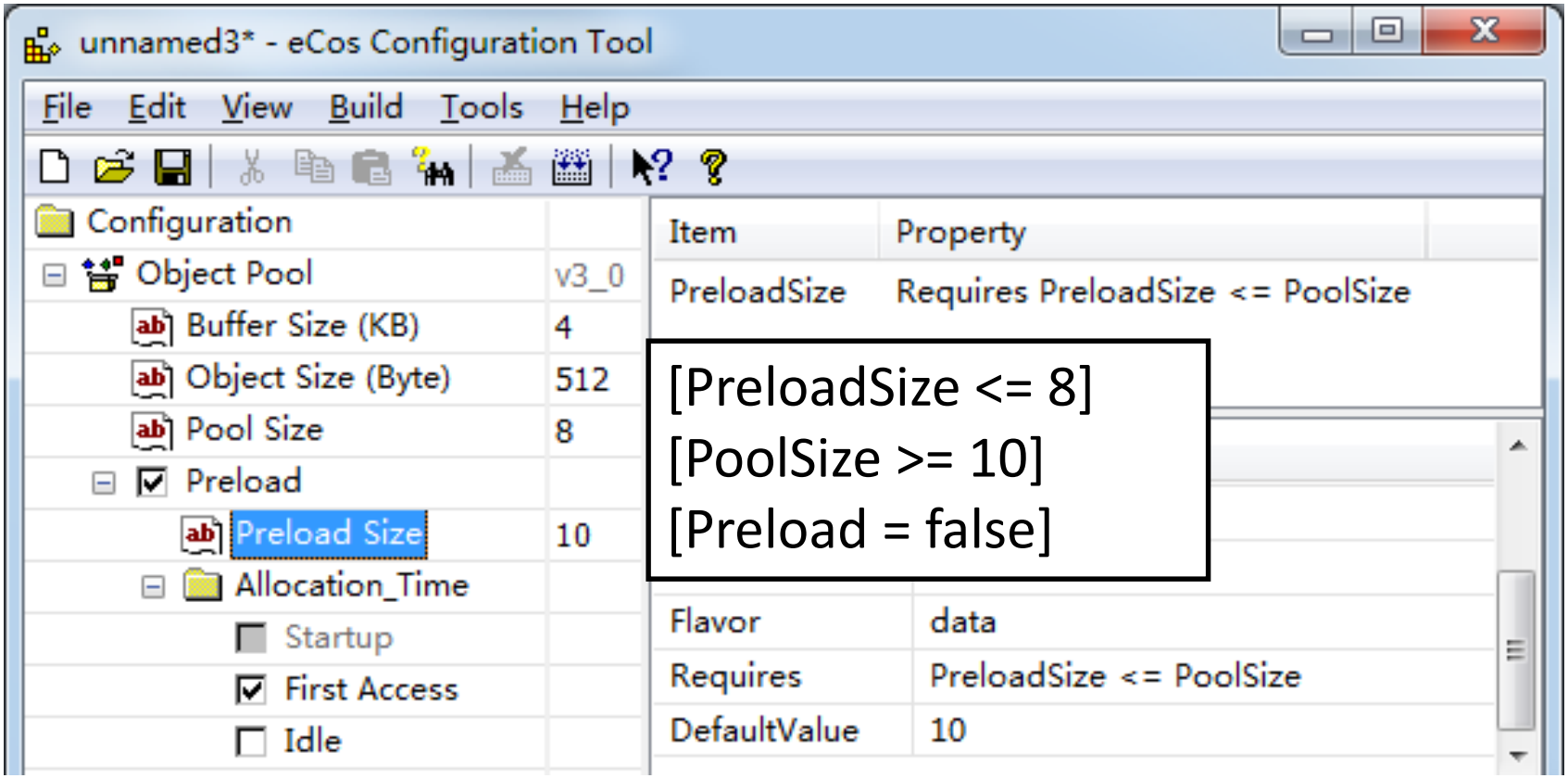


78% eCos users have ecountered situations where the proposed fix is not useful

How to complete fixes



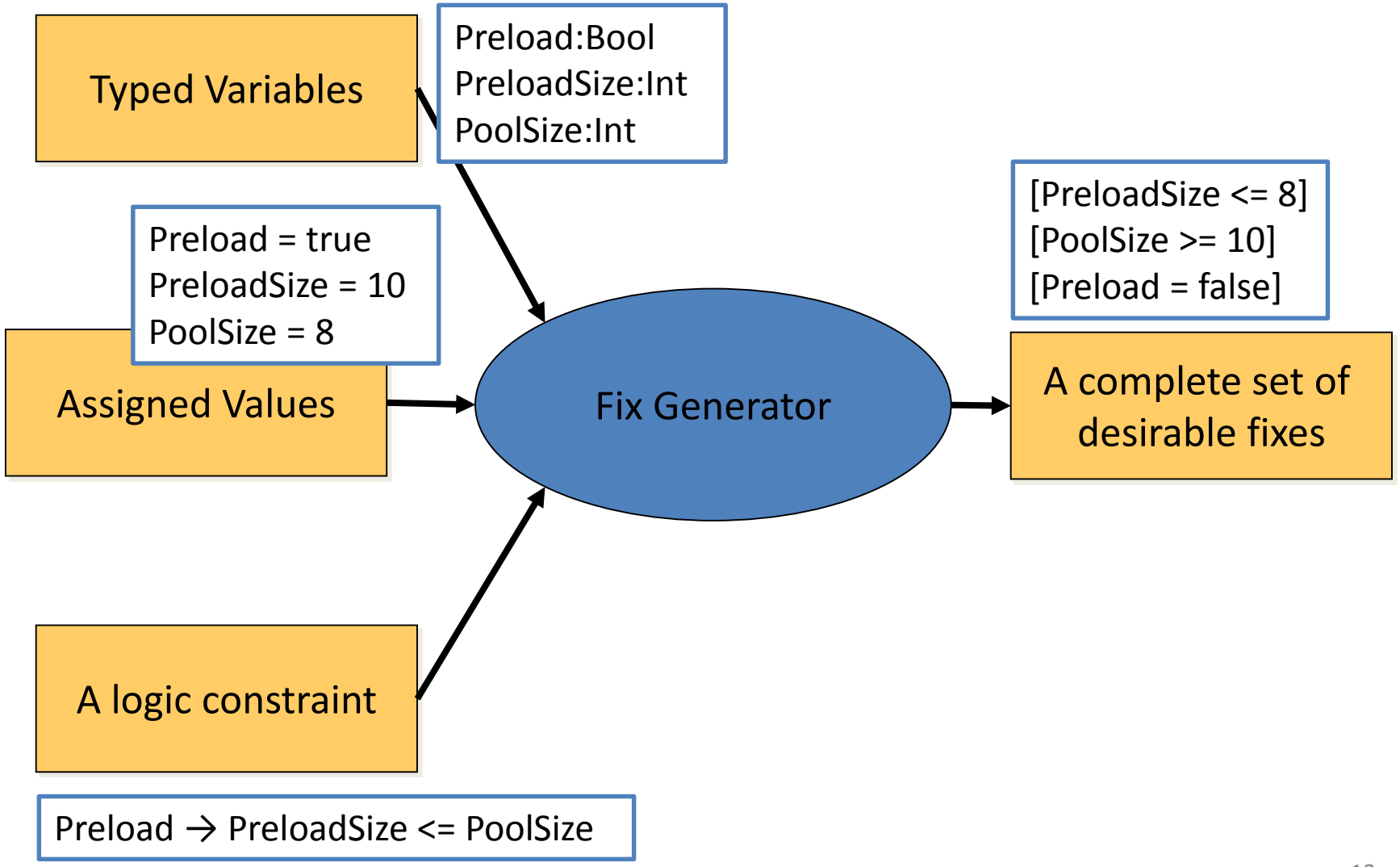
Our Solution – Range Fixes



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 Outline

- Step 1: find the variables to change
  - Basic idea: translating to an SMT problem
    - ① treat configurations also as soft constraints
      1. [soft] Preload = true
      2. [soft] PreloadSize = 10
      3. [soft] PoolSize = 8
      4. [hard] Preload → PreloadSize <= PoolSize
    - ② ask an SMT solver for unsatisfiable cores
      - (1, 2, 3)
    - ③ pick one variable from each core
      - {Preload}, {PreloadSize}, {PoolSize}

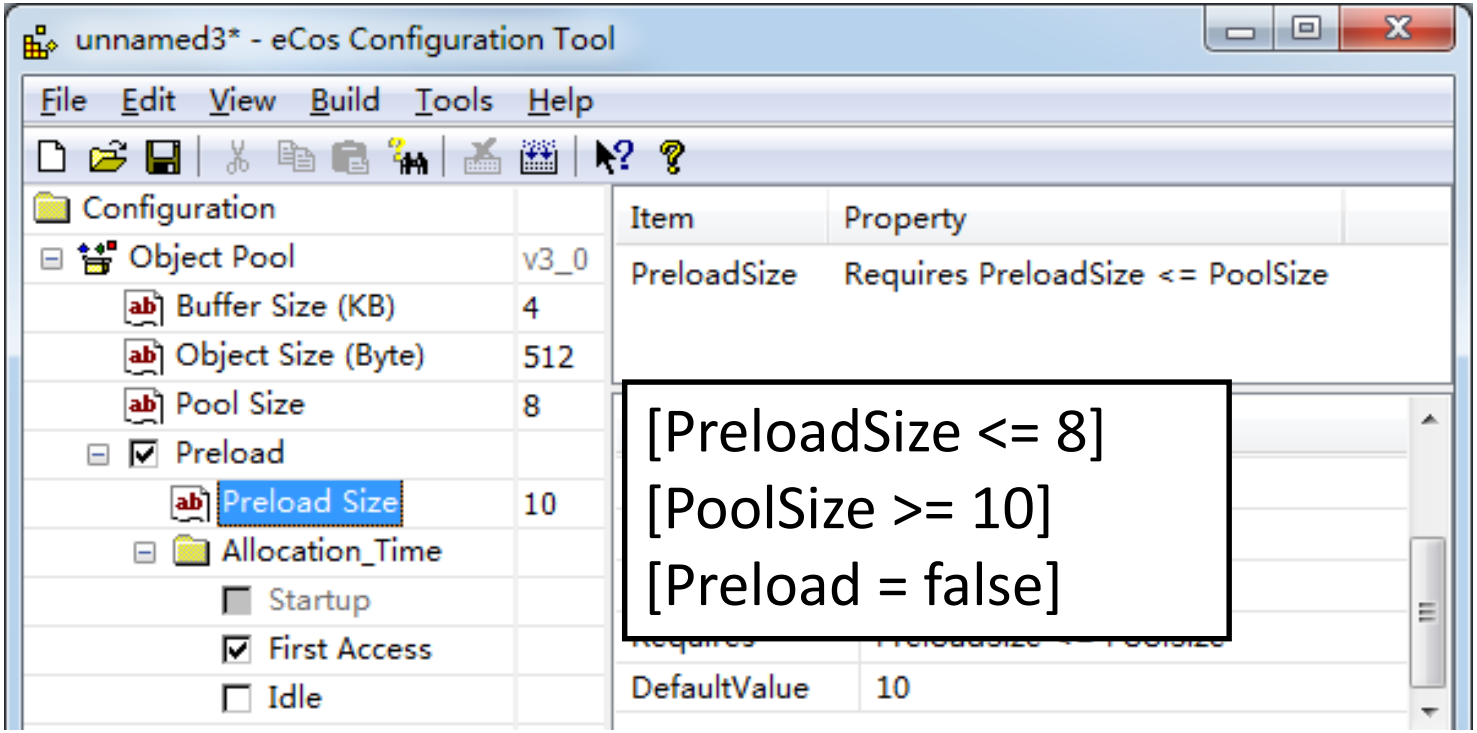
Algorithm Outline

- Step 2: find the range of the variables
  - Basic idea: simplify the constraint
    - Example: {PreloadSize}

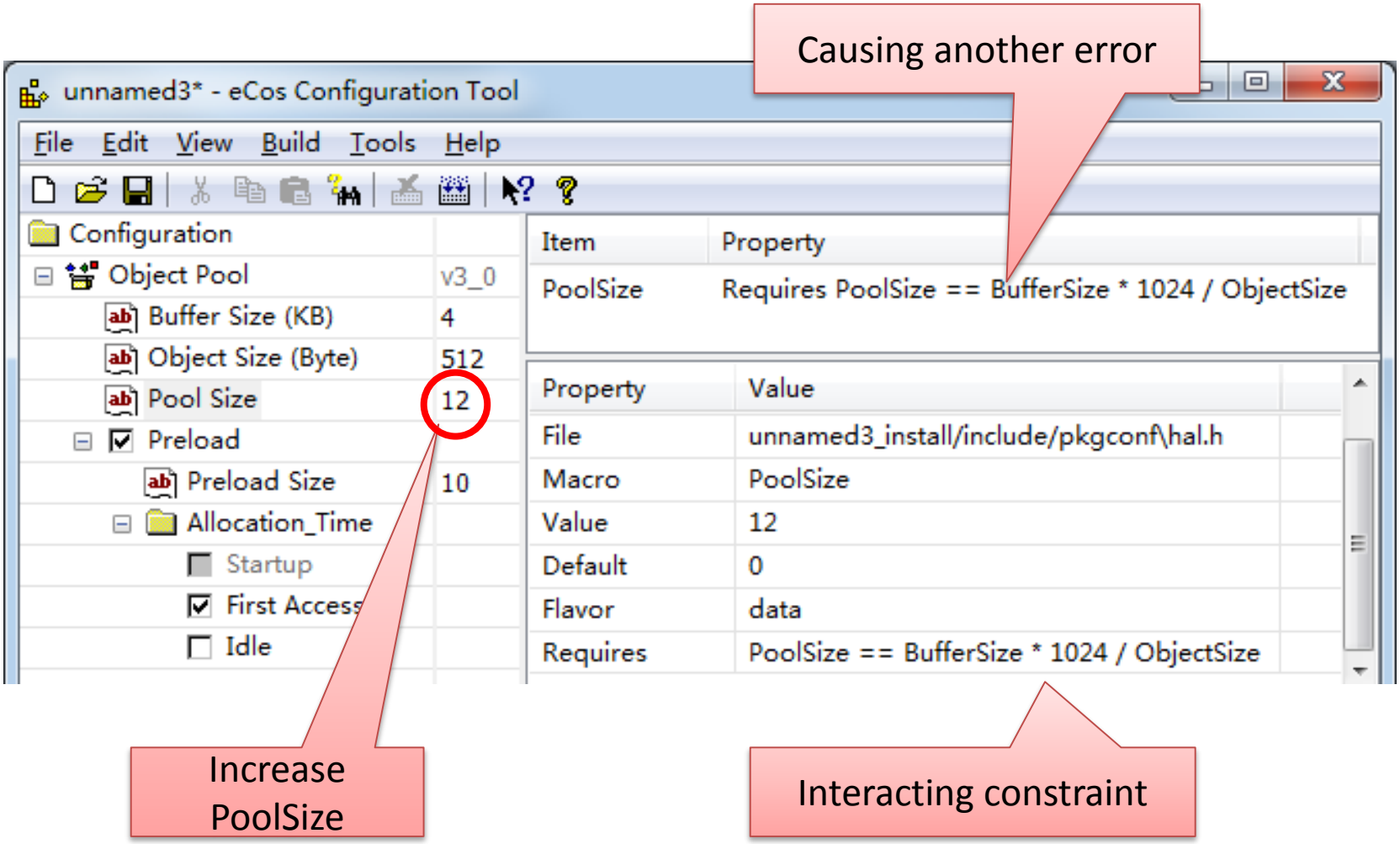
    ① replace unchangeable variables with their current values
      - true → PreloadSize <= 8

    ② simplify the constraint and convert to CNF
      - [PreloadSize <= 8]

Constraint Interaction



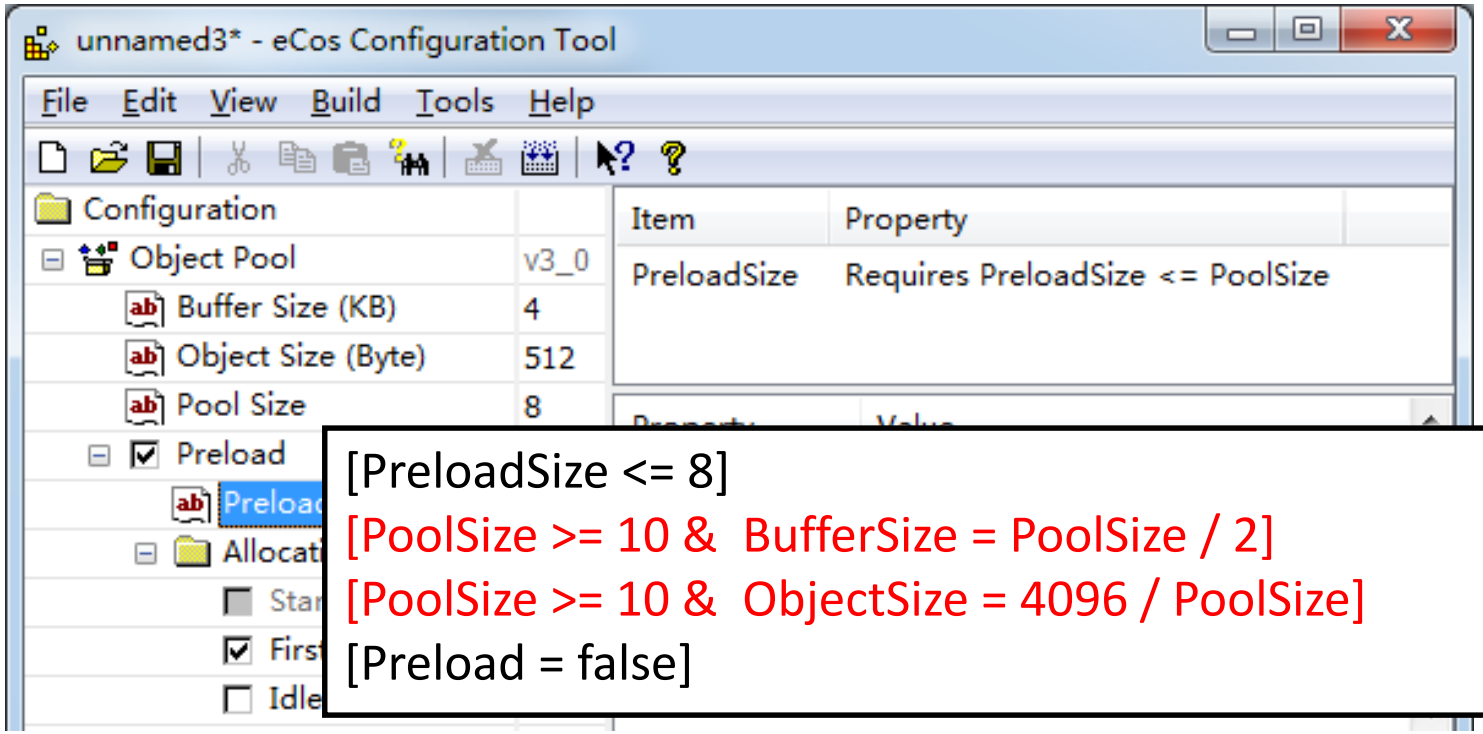
Constraint Interaction



Propagation Strategy

- Conjoin all satisfied constraints with the unsatisfied one into a single constraints
- Example
  - Original Constraints:
    - **Preload → PreloadSize <= PoolSize**
    - PoolSize == BufferSize * 1024 / ObjectSize
  - New Constraints:
    - Preload → PreloadSize <= PoolSize /\ PoolSize == BufferSize * 1024 / ObjectSize

Fixes from Propagation Strategy



Experiments

- Source
  - Version histories from 5 open source projects
  - 535~933 variables, 85~330 constraints
- 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

- Generation Time
  - Average: 50ms
  - Maximum: 250ms
- Complexity of Fix
  - Measured by the number of variables per fix
  - Max:58
  - Median:2
  - 83% of the fix lists contain less than 10 variables

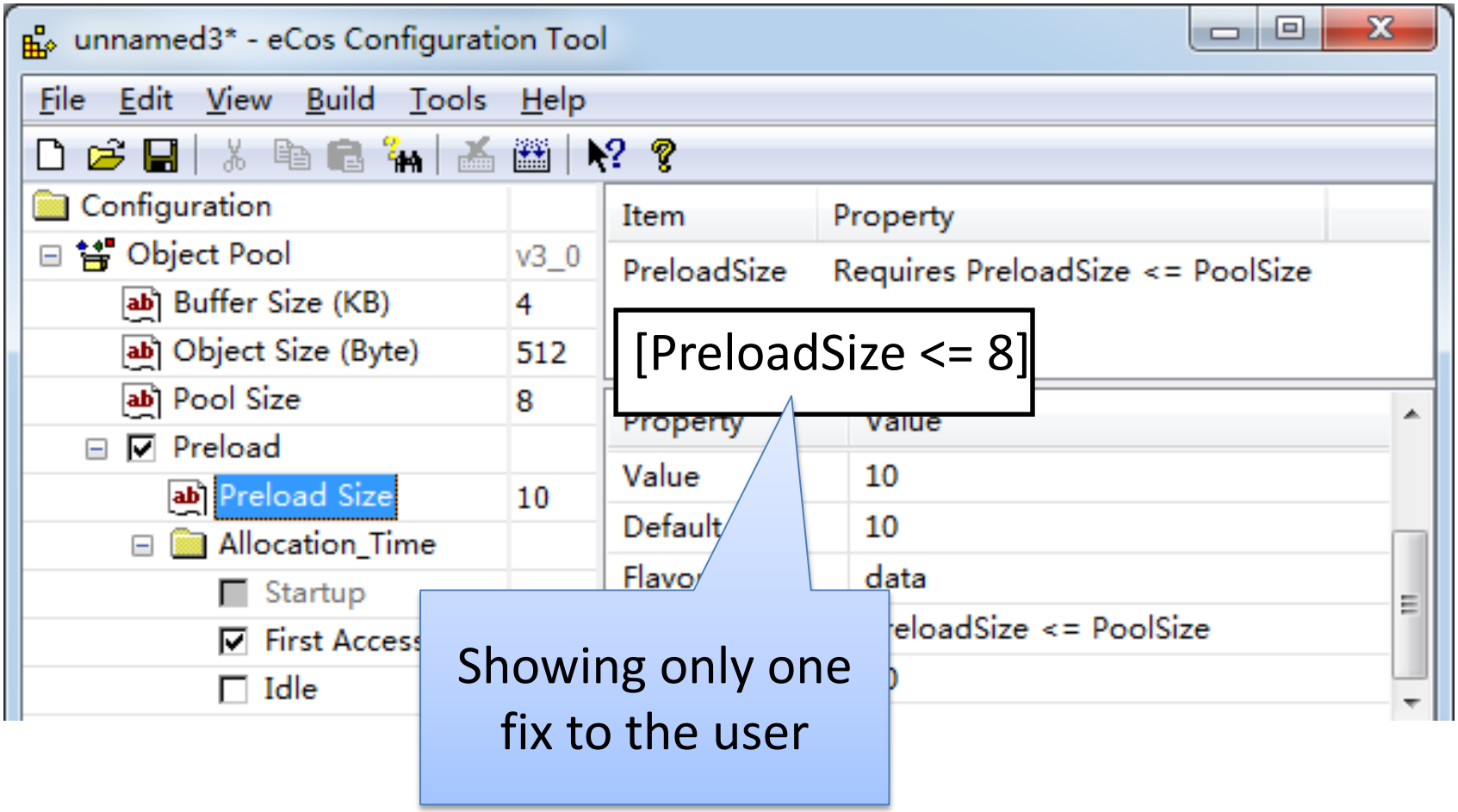
How to guide the users to identify their desirable fixes?

Our Solution

- Use the idea of priority
  - The priority of a variable represents the likelihood of its current value being desirable to the user.

- Two Basic ideas:
  - Show one fix each time that only change variables with lower priorities
  - Dynamically adjust the priority of variables through implicit translation of user feedback

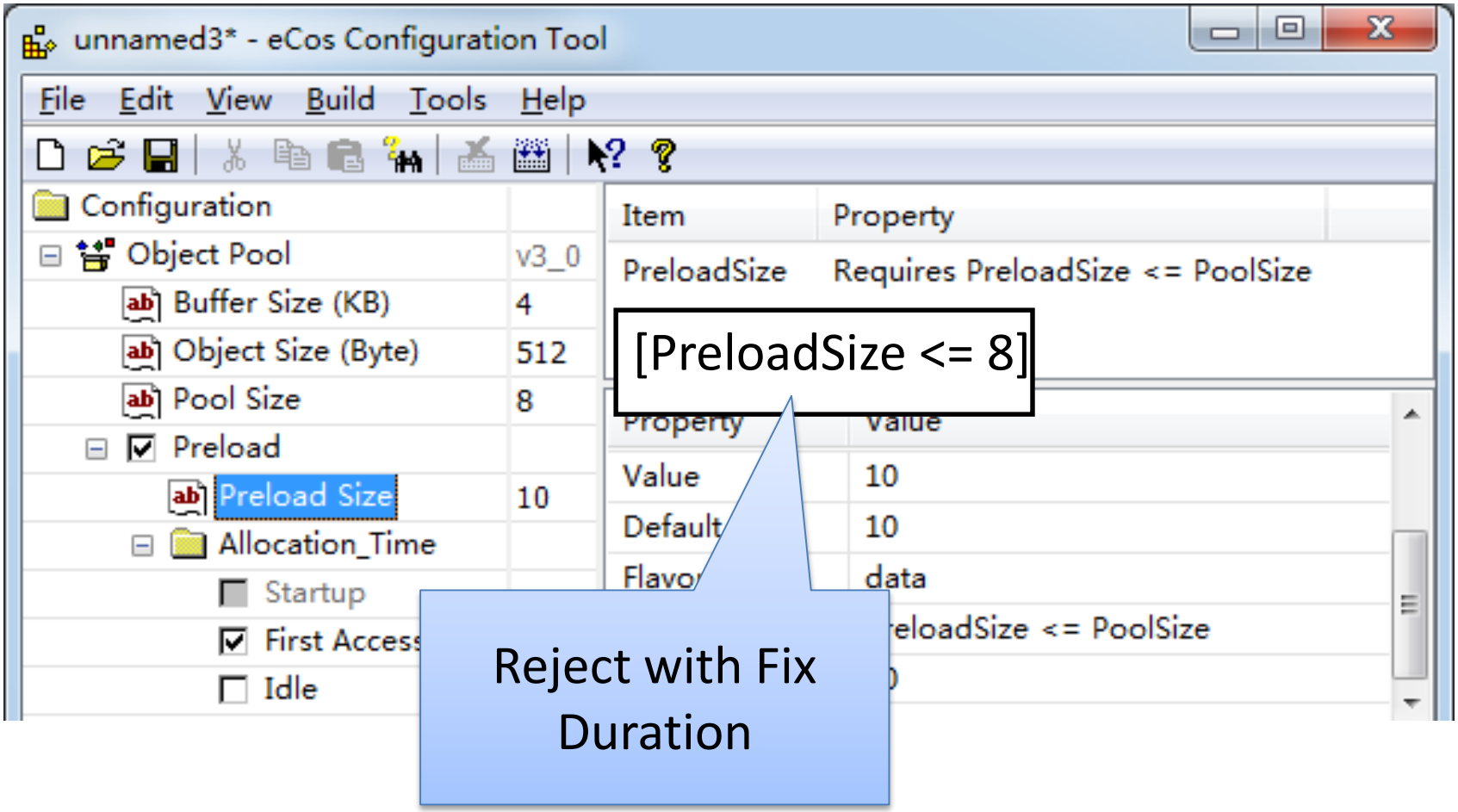
Our Approach



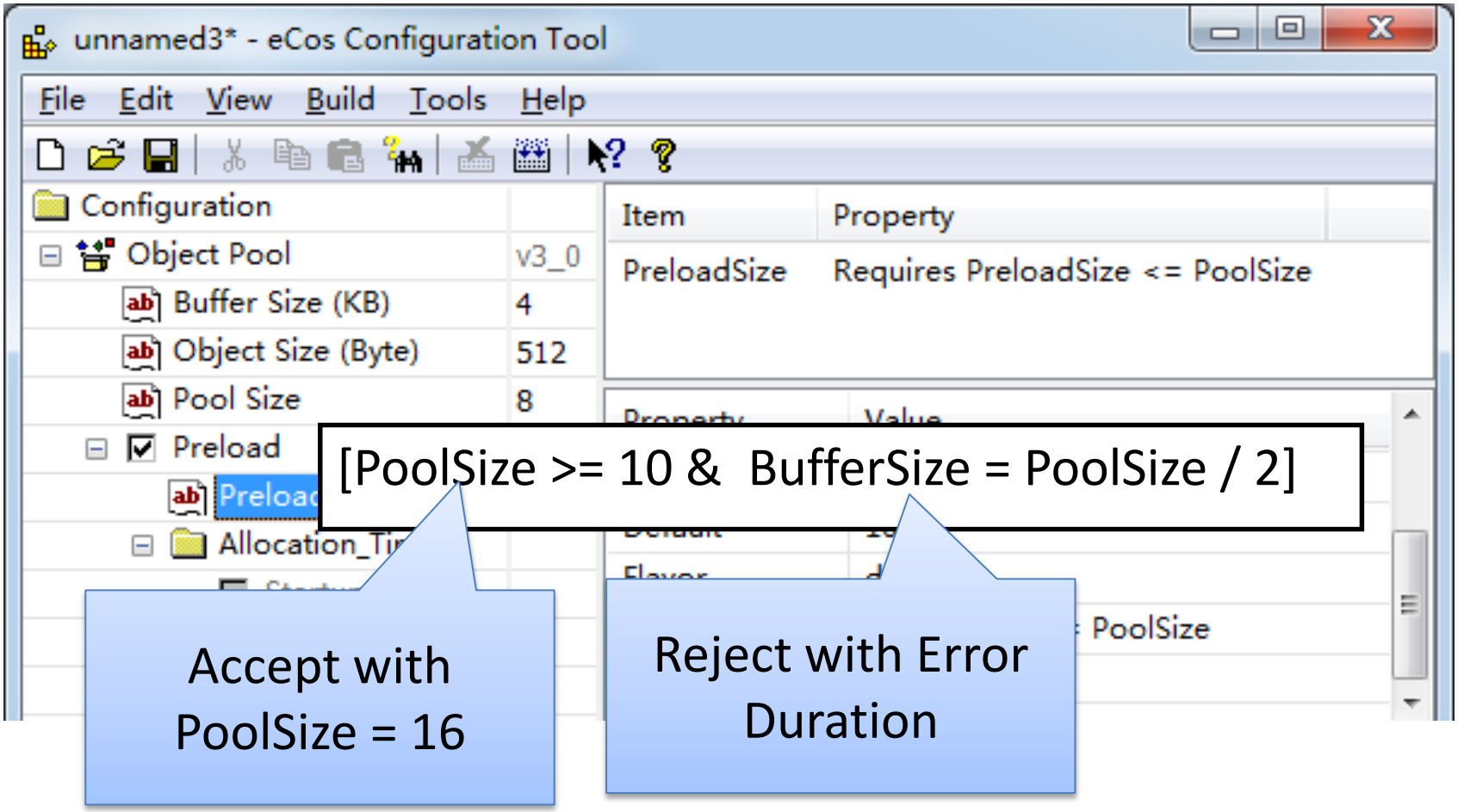
Provide feedback for each variable

- Accept the change (and pick a value)
- Reject the change
  - *Fix* duration
    - Current range is incorrect, future fixes can propose changes for this variable
  - *Error* duration
    - Current value is correct when fixing this error
  - *Permanent* duration
    - Current value is correct in the whole configuration process

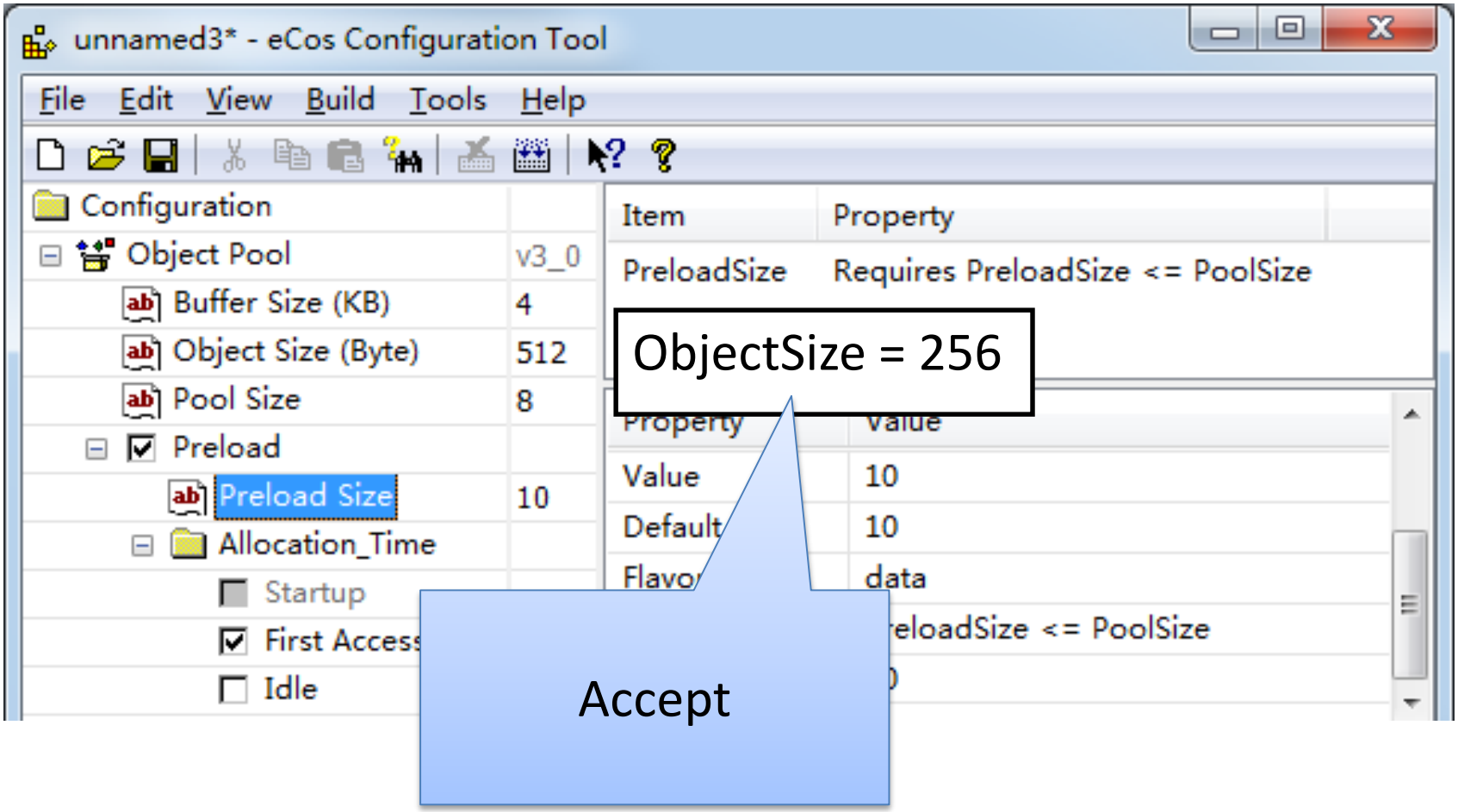
Our Approach



Our Approach

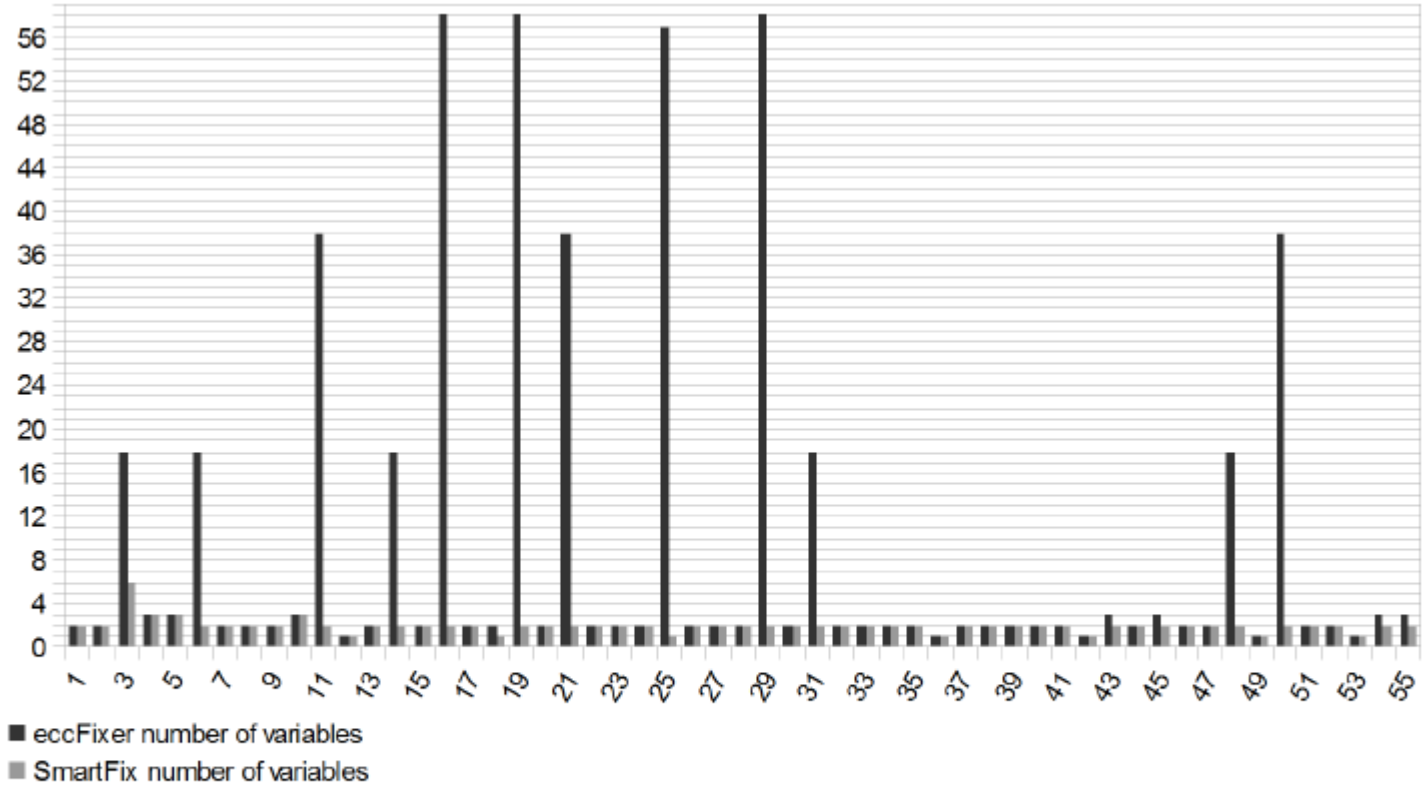


Our Approach



The user feedbacks are stored so that later fixes will be smarter.

Evaluation Results – virtex4



(b) Number of variables

Fig. 6: Experimental results for virtex4

The number of variables is decreased by 23% in average, with a maximum reduction of 98%

Takeaway Messages

- Error Resolution is difficult in configuring large systems
- Solution space can be represented completely and concisely via range fixes
- Large fix list could be controlled by priorities
- Constraint solvers can be used in different ways to solve different problems

Thank you for your attention!

- **References**:

- Yingfei Xiong, Hansheng Zhang, Arnaud Hubaux, Steven She, Jie Wang, Krzysztof Czarnecki. Range Fixes: Interactive Error Resolution for Software Configuration. Submitted to IEEE Transactions on Software Engineering.
- Yingfei Xiong, Arnaud Hubaux, Steven She, Krzysztof Czarnecki. Generating Range Fixes for Software Configuration. In ICSE'12: Proceedings of 34th International Conference on Software Engineering, pages 89-99, June 2012.
- Bo Wang, Leonardo Passos, Yingfei Xiong, Krzysztof Czarnecki, Haiyan Zhao, Wei Zhang. SmartFixer: Fixing Software Configurations based on Self-adaptive Priorities. In SPLC'13: Proceedings of 17th International Software Product Line Conference, August 2013.
- Arnaud Hubaux, Yingfei Xiong, Krzysztof Czarnecki. A User Survey of Configuration Challenges in Linux and eCos. VaMoS'12: Sixth International Workshop on Variability Modelling of Software-intensive Systems, January 2012.
- Leonardo Passos, Marko Novakovic, Yingfei Xiong, Thorsten Berger, Krzysztof Czarnecki, Andrzej Wasowski. A Study of Non-Boolean Constraints in Variability Models of an Embedded Operating System. FOSD'11: 3rd International Workshop on Feature-Oriented Software Development, June 2011.