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學術論文

基于负关联规则的软件缺陷挖掘

NAR-Miner: Discovering Negative Association Rules from Code for Bug Detection

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软件Bug是普遍存在的，且很多Bug难以检测。一种方式是通过挖掘程序中元素之间的关系，并以某个可信度建立元素之间的依赖规则。若程序中出现违反该规则的元素时，则对应的程序片段有可能是一个Bug。这种方法已经被实践证明是行之有效的。然而，已有的基于关联规则挖掘的Bug检测方法，只考虑了程序元素之间的正关联关系，即当某个元素A出现时，另一个元素B也应该出现。实际中，除了正关联规则外，还存在着程序元素之间的负关联规则，即当某个程序元素A出现时，另一个元素B不应该出现。

我们提出了首个基于负关联规则的程序Bug挖掘方法。不同于正关联规则，任何不相关的两个元素通常会行成负关联规则，从而导致了负关联规则爆炸问题。我们通过引入信息熵及一种排序算法，使得所挖掘得到的负关联规则是有意义的。并将之用于Linux内核等开源程序，从中找出了29个疑似Bug，其中23个已经被确认为真实Bug。而基于正关联规则的挖掘方法则仅仅检测到了5个被确认的缺陷。

NAR-Miner: focus on mining negative association rules ($A \Rightarrow \neg B$) to detect bugs that contain unexpected program elements. For $A \Rightarrow \neg B$, A and B are frequent itemsets, while $A \cup B$ is an infrequent itemset. Negative rules with low confidence (e.g., lower than *min_conf*) are filtered out!

$$confidence(A \Rightarrow \neg B) = 1 - \frac{support(A \cup B)}{support(A)}$$

Solve Rule Explosion

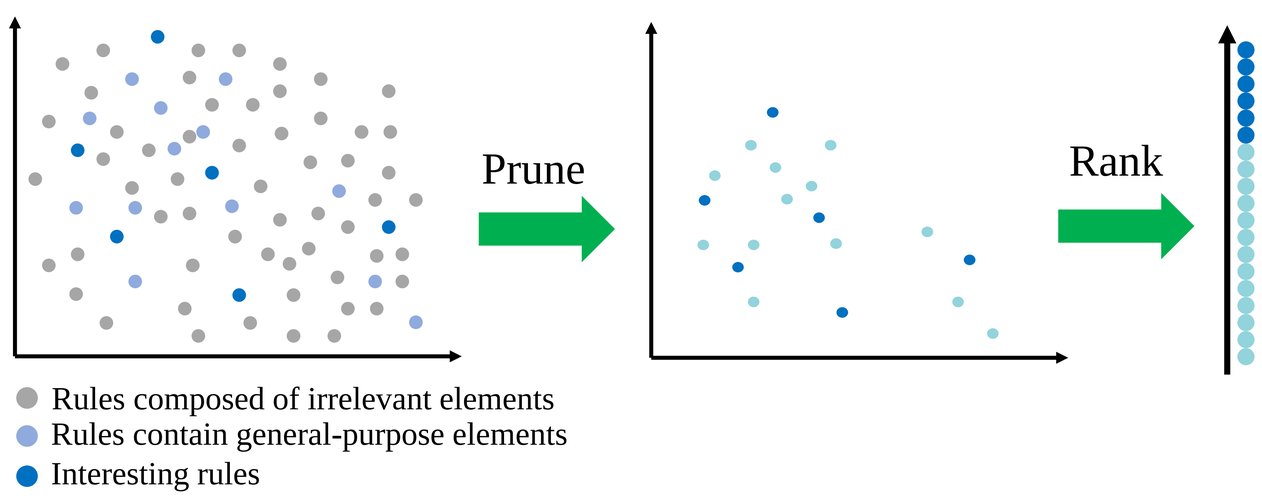
Many mined negative association rules are **uninteresting**, i.e., they do not embody real programming logics. Example: we got > 180,000 negative association rules and about 310,000 violations initially.

- **Pruning**: Introducing semantic constraints during mining to reduce negative association rules consist of irrelevant elements

$$interestingness(R) = \frac{confidence(R)}{\sum H(g_i)}$$

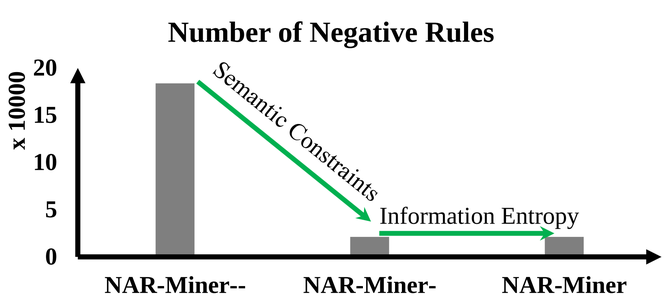
- **Ranking**: Introducing information entropy (信息熵) to measure the generality of program elements and further measure the interestingness of rules. Rank rules according to their interestingness

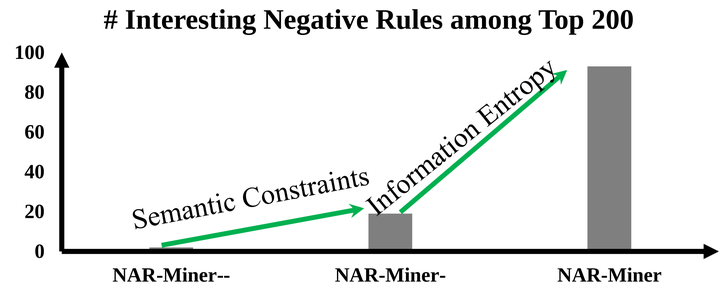
$$H(g) = -\frac{1}{\lg(N)} \sum_{i=1}^{N} p_i * log_2(p_i)$$



Experiment

Target Project	Suspicious Bugs	Confirmed Bugs
Linux-v4.12-rc6	23	17
PostgreSQL-v10.3	2	2
OpenSSL-v1.1.1	2	2
FFmpeg-v4.3.2	2	2
Total	29	23





- Detected 29 suspicious bug; 23 confirmed (at time of paper publications)
- Introducing semantic constraints reduces a large number of negative rules (**about 90%**)
- Improve the accuracy of mined rules (**1% ↑ 9.5%**)
- Improve the accuracy of top ranked rules (**9.5% ↑ 46.5%**)

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