**ECE 653 Project Report**

**Group 63**

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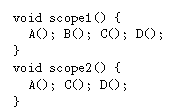
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**Part (1) Building an Automated Bug Detection Tool**

1. **Inferring Likely Invariants for Bug Detection**

In this part, we generate a hashmap (we call it “location” in our script) according to the call graph. The key of the hashmap is the callee function, and the value of the hashmap location is the caller function. In order exclude the redundant and/or repetitive data, both the keys and values are of the SET type.



For example, if the code segment is shown as above, our hashmap can be listed as below:

|  |  |
| --- | --- |
| Set(A) | Set(scope1, scope2) |
| Set(B) | Set(scope2) |
| Set(C) | Set(scope1, scope2) |
| Set(D) | Set(scope1, scope2) |
| Set(A,B) | Set(scope1) |
| Set(A,C) | Set(scope1, scope2) |
| Set(A,D) | Set(scope1, scope2) |
| Set(B,C) | Set(scope1) |
| Set(B,D) | Set(scope1) |
| Set(C,D) | Set(scope1, scope2) |

It should be noted that the above example is only for illustrative purpose, it does not reflect the actual result of our project code.

Then, by looking up the hashmap, we can obtain the number of caller functions corresponding to a callee function or a pair of callee functions, , thereby calculating the support and the confidence. As a result, we can generate the bug according to the rules given in the part1(a).

1. **Finding and Explaining False Positives**

Reasons for the occurrence of false positives could be:

1. Although two methods have to be paired to realize a target function, one of them may be included in a specific method function that only gives a broader definition associated with this method. In such a case, this specific method function does not need to include the other method, since it is not for the target purpose.
2. Although two methods are paired to realize a target function in some circumstances, one of them can be paired with another method to achieve similar functions. In such a case, a false positive is generated if the new pair is regarded as a bug.

I use the code and hash map data structure in (a) to count and list the bug numbers for all the pairs. Then I figure out which 2 pairs can form 10 locations. As seen below, I list the 2 pairs I found and trace back to the source code in /opt/testing/apache\_src to check if the bug is a false positive.

1. Pair (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock) as shown below, which has totally 6 bug locations.

bug: apr\_thread\_mutex\_lock in apr\_dbd\_mutex\_lock, pair: (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock), support: 43, confidence: 95.56%

bug: apr\_thread\_mutex\_lock in apu\_dso\_mutex\_lock, pair: (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock), support: 43, confidence: 95.56%

bug: apr\_thread\_mutex\_unlock in apr\_dbd\_mutex\_unlock, pair: (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock), support: 43, confidence: 91.49%

bug: apr\_thread\_mutex\_unlock in apr\_global\_mutex\_trylock, pair: (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock), support: 43, confidence: 91.49%

bug: apr\_thread\_mutex\_unlock in apr\_global\_mutex\_unlock, pair: (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock), support: 43, confidence: 91.49%

bug: apr\_thread\_mutex\_unlock in apu\_dso\_mutex\_unlock, pair: (apr\_thread\_mutex\_lock, apr\_thread\_mutex\_unlock), support: 43, confidence: 91.49%

Then I use the linux instruction “grep –r” to find out which file contains the corresponding method (please refer to Fig. 2.1). As a result, I check the source code of several locations and I find out some false positives.

As shown in the Fig. 2.2, I read the source code of apr\_dbd\_mutex\_lock(). Apparently, this method apr\_dbd\_mutex\_lock() is used to define mutex\_lock, by using the apr\_thread\_mutex\_lock. There is no need for apr\_dbd\_mutex\_lock() to include an unlock function. In practical use, apr\_dbd\_mutex\_lock() is called by the other functions to perform a lock operation, and apr\_dbd\_mutex\_unlock() is called to perform an unlock operation. In such case, apr\_dbd\_mutex\_lock() does not need an unlock, and similarly apr\_dbd\_mutex\_unlock() does not need a lock. As such, the associated bugs shown in the report from part (a) is false positives.

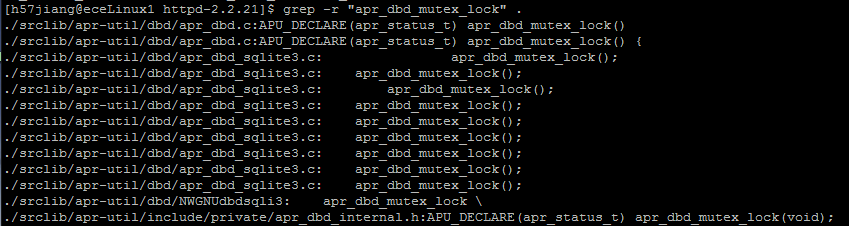


Fig.2.1 use “grep” to search for corresponding pair

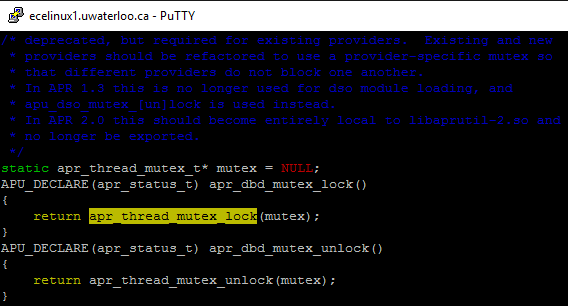


Fig.2.2 the functions apr\_dbd\_mutex\_lock() and apr\_dbd\_mutex\_unlock()

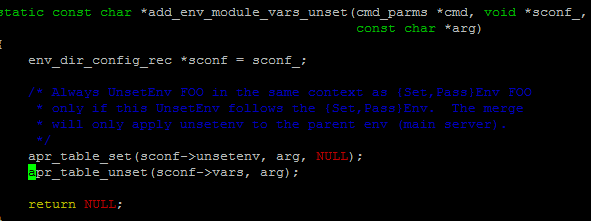
1. Pair (apr\_table\_setn, apr\_table\_unset) as shown below, which has totally 4 bug locations.

bug: apr\_table\_unset in add\_env\_module\_vars\_unset, pair: (apr\_table\_setn, apr\_table\_unset), support: 8, confidence: 66.67%

bug: apr\_table\_unset in ap\_read\_request, pair: (apr\_table\_setn, apr\_table\_unset), support: 8, confidence: 66.67%

bug: apr\_table\_unset in basic\_http\_header, pair: (apr\_table\_setn, apr\_table\_unset), support: 8, confidence: 66.67%

bug: apr\_table\_unset in strip\_headers\_request\_body, pair: (apr\_table\_setn, apr\_table\_unset), support: 8, confidence: 66.67%

Fig.2.3

Then I use the same method as mentioned above to check the pair (apr\_table\_setn, apr\_table\_unset). As shown in Fig. 2.3, I read the source code of add\_env\_module\_vars\_unset. In this function, apr\_table\_unset() follows apr\_table\_set() instead of apr\_table\_setn(). As apr\_table\_set() has already performed a set function, I believe that it is reasonable to have apr\_table\_unset() without a apr\_table\_setn() here.

1. **Inter-Procedural Analysis**

We implement two different solutions for this problem. If you don’t have enough time to review both, please review the solution 1, which works better to reduce false positive.

Solution 1 (please refer to ‘pipair\_java.java’)

1. Idea

The main idea of this approach is to directly examine the bug discovered by the method of part 1(a), and before the bug is printed out. If the bug is turned out to be a false positive, then it is not printed, otherwise it is printed out.

For each bug (e.g., Bug1()) as discovered in part 1(a) and indicated as in a caller function (e.g., Caller1()), Bug1() needs to pair with Pair1() while Caller1() does not contain Bug2(). To seek for Pair1(), we expand one or more functions in Caller1() (we call them neighbour functions of Bug1(), e.g., neighbour1(), neighbour2(), etc.). If we can find Pair1() in at least one of the neighbour functions, then we label this bug as a false positive.

An expansion level is set to control the maximum number of levels by which each neighbour function would expand into. We use DFS to traverse the neighbour functions. The expansion and search for one particular function terminate either when the pair function Pair1() is found or the predetermined expansion level of all the neighbour functions is reached. Please note that the terms “Bug1()”, “Caller1()”, “neighbour1()”, “Pair1()” in this description are for illustrative purpose only, and do not reflect the actual implementations.

In our code implementation, we have created another HashMap (we call it ‘callerCallee’ in our script). CallerCallee stores information about all the caller functions, which is different from the HashMap ‘location’ as mentioned in Part1(a). For example, the key of CallerCallee is caller, and the value is all the callees. The value of CallerCallee are of set types.

More detailed steps are summarized as below:

Step 1: Traverse the call graphs to generate HashMap ‘callerCallee’ which lists caller as key and all the callees as value. The callees are included in a set.

Step 2: Call the HashMap ‘location’ to calculate support and confidence, and determine if a callee function is a bug in a caller function.

Step 3: If a bug is found, then implement DFS to expand the neighbour functions in order to search for the required pair function.

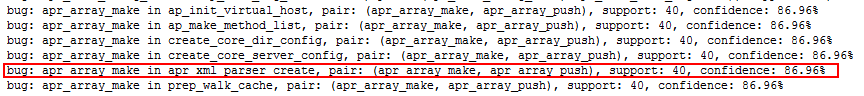
Step 4: If at step 3 the pair function is found in one of the neighbour functions, ignore the bug, otherwise print that bug.

1. Test:

We use test 3 in part 1(a) to test our code for solution 1 in part 1(c). The expansion level is set to 1, 2 and 3 in our test experiment. The test result is summarized in the following table.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Expansion level** | **<Support, Confidence> = <3, 0.65>** | | **<Support, Confidence> = <10, 0.8>** | |
| **Part 1(C)** | **Part 1(A)** | **Part 1(C)** | **Part 1(A)** |
| Level=1 | 174 | 205 | 30 | 34 |
| Level=2 | 166 | 30 |
| Level=3 | 163 | 30 |

As is shown in the table, the number of bugs is reduced compared to the implementation in part 1(A), which means that false positives are identified and removed from the printed bug lines. More specifically, under the standard <Support, Confidence> = <3, 0.65>, part 1(a) found 205 bugs. In comparison, the bugs found by our implementation of part 1(c) are reduced to 174, 166 and 163 when the expansion level is set to 1, 2 and 3 respectively. Likewise, under the standard <Support, Confidence> = <10, 0.8>, part 1(a) found 34 bugs. Among them, 4 false positives are found by our implementation in part1(c). Thus, only 30 bug lines remain.



To give a specific example, the bug line highlighted in red can be found in the report of part 1(a). However, in the solution 1 in part 1(c), this bug line is removed because it is identified as a false positive.

1. More Discussion:

One of the advantages of this approach is that we don’t add more bugs by expanding the functions. Because we aim at reducing the false positives, we only check if the identified bug is the real bug. Compared to those expanding all the sub-functions, our approach improves the time efficiency.

Moreover, we only need to check if an expansion contains the required paired function, no need to have storage space to store the expansion result. Therefore, the storage space is saved.

Solution 2 (please refer to ‘pipair\_java2.java’):

1. Idea

In this solution, we create HashMaps ‘callerCallee’, which works the same as solution 1. We further build up another Hashmap ‘CallerCalleeExtend’. We expand all the possible functions and store the result after expansion in ‘CallerCalleeExtend’. Then we generate the HashMap ‘location’ according to the Hashmap ‘CallerCalleeExtend’. Then the method of searching for bugs based on ‘location’ is the same as in Part 1(a) is employed to search for the bug again.

More detailed steps are listed as below:

Step1: Traverse the call graphs to generate HashMap ‘callerCallee’.

Step2: Expand the functions according to HashMap ‘callerCallee’ to Create HashMap ‘callerCalleeExtend’. The set of callee functions in HashMap ‘callerCalleeExtend’ is set of expanded callee functions from HashMap ‘callerCallee’, which is generated by recursion function called getCalleeExtend().

We use recursion in getCalleeExtend() to expand a caller function into a predetermined level. For example, if the recursion level is set to 2, we will expand a caller function into first level functions and then expand the first level functions one by one into multiple two level functions. The return value is a set that stores expanded callee functions, which are further stored in the HashMap ‘callerCalleeExtend’.

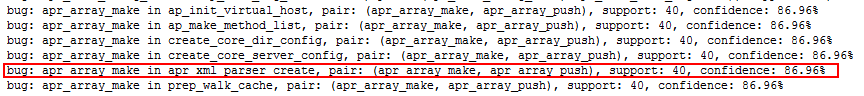
Step3: Update HashMap ‘location’ according to HashMap ‘callerCalleeExtend’. Then search and print bugs using the same solution of part 1(a).

1. Test:

According to the table below, this solution actually add a lot new bugs to the report. The main reason is that after the expansion, the confidences of a lot more pairs reach the threshold.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Expansion level** | **<Support, Confidence> = <3, 0.65>** | | **<Support, Confidence> = <10, 0.8>** | |
| **Part 1(C)** | **Part 1(A)** | **Part 1(C)** | **Part 1(A)** |
| Level=1 | 1630 | 205 | 155 | 34 |
| Level=2 | 5792 | 724 |
| Level=3 | 13556 | 2093 |

However, we can see that this approach is effective to reduce false positive. Refer to the figure below.



Similar to solution 1, we don’t find the bug line as highlighted in the above figure after implementing the solution 2.

1. More Discussion:

Compared to solution 1, this approach needs more memory space for HashMap ‘callerCalleeExtend’ to store the function relation information after expansion. After implementation, more bugs jump out.

Another question is whether to expand main function. The debate is that because main function includes all functions, any two of callee functions will turn to be paired if the expansion level is high. However the pipair in main shows some functions should appear together, for example, if there are lock and unlock functions in main, the support of this pipair will add one, and this support will influence the MAY Belief that the lock and unlock functions should appear together. So we prefer to expand main function.

The final question is whether to delete caller function after expanding that function. If we do not delete caller function, there may be more pipairs including caller function, but useless to analyze false positive. And the number of bug increases rapidly with raising expansion level, we choose to delete caller function to reduce meaningless pipair.

**Part (2) Using a Static Bug Detection Tool**

1. **Resolving Bugs in Apache Commons**
2. **CID 10065**

Missing break in switch (MISSING\_BREAK)

**Classification:** False Positive

**Explanation:**

In “case 3”( BooleanUtils.java from line 628 to line 640), if “ ch == ‘y’/’Y’ ”,it will return the corresponding Boolean vaule after checking whether it equals to “yes” or “YES”.Due to the lack of “break”,it will execution “case4"if it does not satisfy any case in “case 3”,and it will also does not any case of “case 4” since the unequal length.Finally,it will return false,which does not modify the output.

1. **CID 10066**

CN:Bad implementation of cloneable idiom(FB.CN-IDIOM)

**Classification:** False Positive

**Explanation:**

In this class, it implements Cloneable interface,but have clone() method is not called in it.It will waste the space.However,it will not cause the problem.

1. **CID 10067**

Dm: Dubious method used (FB.DM\_DEFAULT\_ENCODING)

**Classification:** Intentional

**Original code**:(NestableDelegate.java line292)

PrintWriter pw = new PrintWriter(out, false);

**Re-factory:**

PrintWriter pw = new PrintWriter((new OutputStreamWriter(out,”UTF-8”), false);

**Explanation:**

Different environments may have different defauly character encodings. you can control the character encoding the characters .should be written in such that they won't eventually end up as gibberish.

1. **CID 10068**

Dm: Dubious method used (FB.DM\_NEXTINT\_VIA\_NEXTDOUBLE)

**Classification:** Intentional

**Original code:**

110        **return** (int)(Math.random() \* n);

**Re-factory:**

110        **return** (int)( Random.nextInt(n));

**Explanation:**

Math.random() requires about twice the processing to generate an integer and is subject to synchronization. Random.nextInt(n) uses Random.next() less than twice on average- it uses it once, and if the value obtained is above the highest multiple of n below MAX\_INT it tries again, otherwise is returns the value modulo n (this prevents the values above the highest multiple of n below MAX\_INT skewing the distribution), so returning a value which is uniformly distributed in the range 0 to n-1.Therefore Random.nextInt(n) is more efficient and less biased.

1. **CID 10069**

Eq: Problems with implementation of equals() (FB.EQ\_COMPARING\_CLASS\_NAMES)

**Classification:** Bug

**Faulty lines:**( Enum.java line 552)

**if** (other.getClass().getName().equals(**this**.getClass().getName()) == false)

**In this code,it wants to determine whether the object other is the same class as this object.However,the equal method just compare these two object if have the same name.Therefore,it can not achieve the goal of the code and is just a bug.**

**Bug fix:** (To compare the class of an object to the intended class, the getClass() method and the comparison operator "==" should be used.)

**if** (other.getClass() == **this**.getClass())== false)

**we just remove getName() method and use comparison operator "==".**

1. **CID 10070**

Eq: Problems with implementation of equals() (FB.EQ\_COMPARING\_CLASS\_NAMES)

**Classification:** Bug

**Faulty lines**:( Enum.java line 598)

**if** (other.getClass().getName().equals(**this**.getClass().getName()) == false)

**In this code,it wants to determine whether the object other is the same class as this object.However,the equal method just compare these two object if have the same name.Therefore,it can not achieve the goal of the code and is just a bug.**

**Bug fix:** (To compare the class of an object to the intended class, the getClass() method and the comparison operator "==" should be used.)

**if** (other.getClass() == **this**.getClass())== false)

**we just remove getName() method and use comparison operator "==".**

1. **CID 10071**

ES: Checking String equality using == or != (FB.ES\_COMPARING\_PARAMETER\_STRING\_WITH\_EQ)

**Classification**: Intentional

**Original code:**(BooleanUnits.java line 614)

614        **if** (str == "true")

**Re-factory :**

614        **if** (str.equals("true"))

**Explanation:**

According to the comments above the method and above this code line, the parameter of method toBoolean(String str) is interned strings, so using “==” to compare str with “true” would not cause problem.

But, to achieve scalability, if the parameter str is not a String constant or interned string, the result of this statement would not be functionally right. Using “equals” is a better way to promise the program function.

1. **CID 10072**

ES: Checking String equality using == or != (FB.ES\_COMPARING\_PARAMETER\_STRING\_WITH\_EQ)

**Classification:**Intentional

**Original code** :(StringUtils.java line 4865)

4865        **if** (str1 == str2)

**Re-factory :**

4865        **if** (str1.equals("str2"))

**Explanation:**

According to the comments above the method and above this code line, the parameter of method indexOfDifference(String str1, String str2)

is interned strings, so using “==” to compare str1 with “str2” would not cause problem.

But to achieve scalability, if the parameter str1 or str2 is not a String constant or interned string, the result of this statement would not be functionally right. Using “equals” is a better way to promise the program function.

1. **CID 10073**

ES: Checking String equality using == or != (FB.ES\_COMPARING\_PARAMETER\_STRINGS\_WITH\_EQ)

**Classification:** False Positive

**Original code:** In DurationFormatUnits.java

1. 409            **else** **if** (value == S)
2. 405            **else** **if** (value == s)
3. 401 **else** **if** (value == m)
4. 397 **else** **if** (value == H)
5. 393 **else** **if** (value == d)
6. 389 **else** **if** (value == M)
7. 385 **else** **if** (value == y)

**Explanation:**

380            Object value = token.getValue();

“value” is a constant which is defined in line 380.And for

else if statement,both the right hand and the left hand

are constant strings,so they can be compared by “==”.

**CID 10074**

ES: Checking String equality using == or != (FB.ES\_COMPARING\_PARAMETER\_STRING\_WITH\_EQ)

**Classification:**False Positive

**Explanation:**

previous.getValue() is constant in the source file, variable value just be assigned to a String value, but not instantiate a new object. So they can be compared using “==”.

**CID 10075**

IM: Questionable integer math (FB.IM\_AVERAGE\_COMPUTATION\_COULD\_OVERFLOW)

**Classification:**Intentional

**Original code :** In Entities.java(line 649)

649                int mid = (low + high) >> 1;

**Re-factory:**

649                int mid = (low + high) >>> 1;

**Explanation:**

If the result of (low + high) is zero or positive,it will not cause the problem.While the result is negative, “>>” will cause the wrong answer.

The >> operator shifts a 1 bit into the most significant bit if it was a 1, and the >>> shifts in a 0 regardless.

(low + high) >> 1 keeps the sign bit of the original, so a negative value for a gives a negative result.

(low + high)  >>> 1 works by introducing a zero sign bit, so the result cannot be negative for any (low + high).

**CID 10076**

NP: Null pointer dereference (FB.NP\_BOOLEAN\_RETURN\_NULL)

**Classification:**Intentional

**Solution:**left as-is

**Explanation:**

In general,it is not reasonable to return null,which may lead to null-pointer exceptions.While in the above comments,it is said that:

 61*\* @return the negated Boolean, or <code>null</code> if <code>null</code> input*

Therefore ,This method allows to return null, So, it’s an

intentional warning. According to the function of the

method, it should be left as-is.

**CID 10077**

NP: Null pointer dereference (FB.NP\_BOOLEAN\_RETURN\_NULL)

**Classification:**Intentional

**Solution:**left as-is

**Explanation:**

In general,it is not reasonable to return null,which may lead to null-pointer exceptions.While in the above comments,it is said that:

305*\* @return Boolean.TRUE, Boolean.FALSE, or <code>null</code>*

Therefore ,This method allows to return null, So, it’s an

intentional warning. According to the function of the

method, it should be left as-is.

**CID 10078**

NP: Null pointer dereference (FB.NP\_BOOLEAN\_RETURN\_NULL)

**Classification:**Intentional

**Solution:**left as-is

**Explanation:**

In general,it is not reasonable to return null,which may lead to null-pointer exceptions.While in the above comments,it is said that:

221*\* @return Boolean.TRUE if non-zero, Boolean.FALSE if zero,*

222*\*  <code>null</code> if <code>null</code> input*

223*\*/*

Therefore ,This method allows to return null, So, it’s an

intentional warning. According to the function of the

method, it should be left as-is.

**CID 10079**

NP: Null pointer dereference (FB.NP\_BOOLEAN\_RETURN\_NULL)

**Classification:**Intentional

**Solution:**left as-is

**Explanation:**

In general,it is not reasonable to return null,which may lead to null-pointer exceptions.While in the above comments,it is said that:

336*\* @return Boolean.TRUE, Boolean.FALSE, or <code>null</code>*

Therefore ,This method allows to return null, So, it’s an

intentional warning. According to the function of the

method, it should be left as-is.

**CID 10080**

NP: Null pointer dereference (FB.NP\_BOOLEAN\_RETURN\_NULL)

**Classification:**Intentional

**Solution:**left as-is

**Explanation:**

In general,it is not reasonable to return null,which may lead to null-pointer exceptions.While in the above comments,it is said that:

502     \* <p><code>'true'</code>, <code>'on'</code> or <code>'yes'</code>

503     \* (**case** insensitive) will **return** <code>true</code>.

504     \* <code>'false'</code>, <code>'off'</code> or <code>'no'</code>

505     \* (**case** insensitive) will **return** <code>false</code>.

506     \* Otherwise, <code>null</code> is returned.</p>

Therefore ,This method allows to return null, So, it’s an

intentional warning. According to the function of the

method, it should be left as-is.

**CID 10081**

NP: Null pointer dereference (FB.NP\_BOOLEAN\_RETURN\_NULL)

**Classification:**Intentional

**Solution:**left as-is

**Explanation:**

In general,it is not reasonable to return null,which may lead to null-pointer exceptions.While in the above comments,it is said that:

557*\* @return the Boolean value of the string,*

558*\*  <code>null</code> if no match or <code>null</code> input*

Therefore ,This method allows to return null, So, it’s an

intentional warning. According to the function of the

method, it should be left as-is.

**CID 10082**

REC: RuntimeException capture (FB.REC\_CATCH\_EXCEPTION)

**Classification:**Intentional

**Original code :**In ExceptionUnits.java (line 97)

 97        **catch** (Exception e)

**Re-factory:**

 97        **catch** (RuntimeException e)

**Explanation:**

In Java, there are two types of exceptions: checked exceptions and un-checked exceptions. A checked exception must be handled explicitly by the code, whereas, an un-checked exception does not need to be explicitly handled.

Any exception that derives from "Exception" is a checked exception.

Any exception that derives from "RuntimeException" is an un-checked exceptions.

Generally,throwing a checked exception will not cause the problem.While the method could not be normally handle an un-checked exceptions .  RuntimeExceptions do not need to be explicitly handled by the calling code.

**CID 10083**

Se: Incorrect definition of Serializable class (FB.SE\_BAD\_FIELD)

**Classification:** Intentional

**Original code:**In FastDateFormat.java (line 137)

137    **private** Rule[] mRules;

**Re-factory:**

137    **private transient** Rule[] mRules;

**Explanation:**

By default, all of object's variables get converted into a persistent state. In some cases, you may want to avoid persisting some variables because you don't have the need to persist those variables. So you can declare those variables as transient. If the variable is declared as transient, then it will not be persisted.

**CID 10084**

UrF: Unread field (FB.URF\_UNREAD\_FIELD)

**Classification:**False Positive

**Explanation:**

 85            **this**.key = key;

the key has never been read,and it seems always same with hash and is redundant .But it will not cause the problem.

1. **Analyzing Your Own Code**

1.After running Coverity on my own code for part1 (a),1 error is defected as following:



1. **CID 10090**

Dm: Dubious method used(FB.DM\_DEFAULT\_ENCODING)

Original Code: line 34 in pipair\_java.java



Fixed Code:



Explaination:  Different environments may have different defauly character encodings.This would guarantee that, given an input file that uses encoding "UTF-8", it will be parsed in the same way regardless of what machine you are executing your program in.

2.run Coverity on fixed code, 0 error is defected.



3.the reasons for only finding one error:

1)Maybe there are some errors not documented in the Coverity, and these errors covered in our code can not be defected.

2)As the Coverity is a static analysis tool,some errors ,such as memory leaks and time dependencied, can only be defected by the dynamic tool

**Appendix :**

the output from Coverity:

|  |  |
| --- | --- |
| **Error#1** | |
| **Meta Variable** |  |
| Checker | FB.DM\_DEFAULT\_ENCODING |
| File | /home/c392liu/sa\_output/pipair\_java.java |
| Function | pipair\_java.main(java.lang.String[]) |
| Ordered | true |
| **Event** | |
| **Variable** |  |
| main | true |
| tag | defect |
| description | {CovLStr{v1}{Found reliance on default encoding: {0}.}{new java.util.Scanner(InputStream)}} |
| line | 34 |