



缺陷修复技术

熊英飞

北京大学软件工程研究所



报告人介绍 – 熊英飞

- 2000~2004，电子科技大学大学本科
- 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

北京大学软件工程研究所



- 国内最早开展软件工程专业研究、规模最大、最有影响力的软件工程专业研究团队
- 院士三名（含双聘一名），博士生导师**10**名，硕士生导师**13**名
- 在软件工程顶级会议发表论文数为大陆第一名
- 发表了中国大陆第一篇ICSE，第一篇FSE，第一个CCF A类会议上的杰出/最佳论文奖

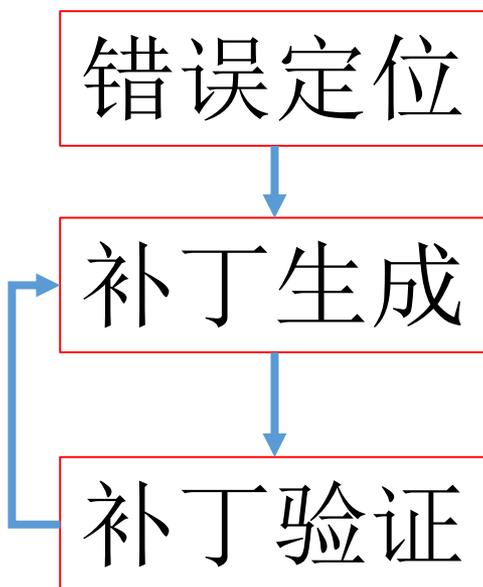


缘起

- 人和Bug的斗争从来没有停止过
- 缺陷检测：到底有没有Bug
 - 从上世纪60年代开始
 - 代表技术：软件测试、软件验证
- 缺陷定位：Bug在哪里
 - 从上世纪90年代开始
 - 代表技术：统计性调试
- 缺陷修复：自动消除Bug
 - 约从2000年之后开始
 - 代表技术：生成-验证缺陷修复技术



“生成-验证”缺陷修复





代表性工作

- GenProg

- [Westley Weimer: ICSE'09, GECCO'09, CACM'10, ICSE'12]
- 错误定位：采用统计性调试
- 补丁生成：
 - 基本操作：复制其他语句/删除语句
 - 采用遗传算法从基本操作合成补丁
- 补丁验证：运行程序中的测试验证补丁
- 实证研究：55/105，8\$/bug

- 引发一系列相关工作

- PAR, MintHint, AutoRepair, RSRepair, SemFix, DirectFix, ...

- 程序员的前景一片光明，躺着完成工作的日子指日可待。



转折

- [Qi-ISSTA'15]
 - GenProg被认为修复的55个缺陷中，只有2个是正确的
 - 根本原因：通过测试并不代表是正确的修复
- [Le Goues-FSE'15]
 - 详细实验了GenProg, AE等多个主流修复方法，采用了更大的数据集，更多的测试集
 - 结果基本一致
- 其他后续工作
 - SPR, Prophet, Angelix
 - 补丁的正确率最好也只有30%左右



原因分析

- 软件中的规约通常是不充分的
- 已有缺陷修复技术仅已满足规约为目标，但通过规约并不意味着是正确的修复



我们的方法

- 获取领域知识来修复缺陷
 - 有经验的程序员在不知道软件规约的情况下也能修复很多缺陷
 - 获取有经验的程序员的领域知识，利用领域知识修复特定类型的缺陷
- 我们小组的工作
 - 设计编程语言编码领域知识
 - 从已有数据自动获取领域知识
 - 针对重要缺陷类型设计专门修复算法



基于问答网站分析的 复发崩溃缺陷的自动修复

高庆，张汉生，王杰，
熊英飞，张路，梅宏

北京大学软件工程研究所
发表于ASE'15



示例

```
29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
33     switch (action) {
...     ...
51     }
52 }
```

context: Context

应该为

context.getApplicationContext() : ApplicationContext

java.lang.RuntimeException: Unable to start receiver : android.content

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android - "IntentReceiver components are not allowed to ...
stackoverflow.com/.../intentreceiver-components-are-not-allowed-to-regi...
Jul 24, 2014 - "IntentReceiver components are not allowed to register to receive ...
ACTION_BATTERY_CHANGED); Intent batteryStatus = c. ... RuntimeException: Unable to start receiver ...
ActivityThread.main(ActivityThread.java:4627) at java.lang.reflect. ... NativeStart.main(Native Method) Caused by: android.content

android - Battery changed broadcast receiver crashing app ...
stackoverflow.com/.../battery-changed-broadcast-receiver-crashing-app-...
Feb 27, 2013 - Battery changed broadcast receiver crashing app on some phones. No
... PowerConnectionReceiver"> <intent-filter> <action android:name="android.intent
.action. ... RuntimeException: Unable to start receiver com.doublep.wakey.
ReceiverCallNotAllowedException: IntentReceiver components are not ...

android - Want app to execute some code when phone is ...
stackoverflow.com/.../want-app-to-execute-some-code-when-phone-is-pl...
Jun 29, 2012 - ACTION_BATTERY_CHANGED)); int plugged = intent. ... The code
errors out with: *FATAL EXCEPTION: main:: java.lang.RuntimeException: Unable to
start receiver com.example.ChargingOnReceiver: android.content. ... IntentReceiver
components are not allowed to register to receive intents *. I kind of ...

push notification - Unable to start receiver com.parse ...
stackoverflow.com/.../unable-to-start-receiver-com-parse-parsebroadcastr...
Feb 11, 2013 - ParseBroadcastReceiver on Trigger.io Android app. No problem. ...

Stack Overflow is a community of 4.7 million programmers, just like you, helping each other. It only takes a minute:

"IntentReceiver components are not allowed to register to receive intents to determine Battery level"



I am trying to get Battery info from my Application following the guidelines at <http://developer.android.com/training/monitoring-device-state/battery-monitoring.html>

This is the method is came up with to check the battery level:

```
public void sendBatteryInfoMessage(){  
  
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_CHANGED);  
    Intent batteryStatus = c.registerReceiver(null, iFilter);  
  
    ...  
  
}
```

Instead of:

```
context.registerReceiver(null, new IntentFilter(Intent.ACTION_BATTERY_CHANGED));
```

use:

```
context.getApplicationContext().registerReceiver(null, new IntentFilter(Intent.ACTION_BATTERY_CHANGED));
```

This is annoying -- registerReceiver() should be smarter than this -- but it's the workaround for this particular case.

share improve this answer



示例

```
29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
33     switch (action) {
34         ...
35         ...
36     }
37 }
38 }
```



```
final float bl=BatteryHelper.level(
    context.getApplicationContext());
```



✓ 修复

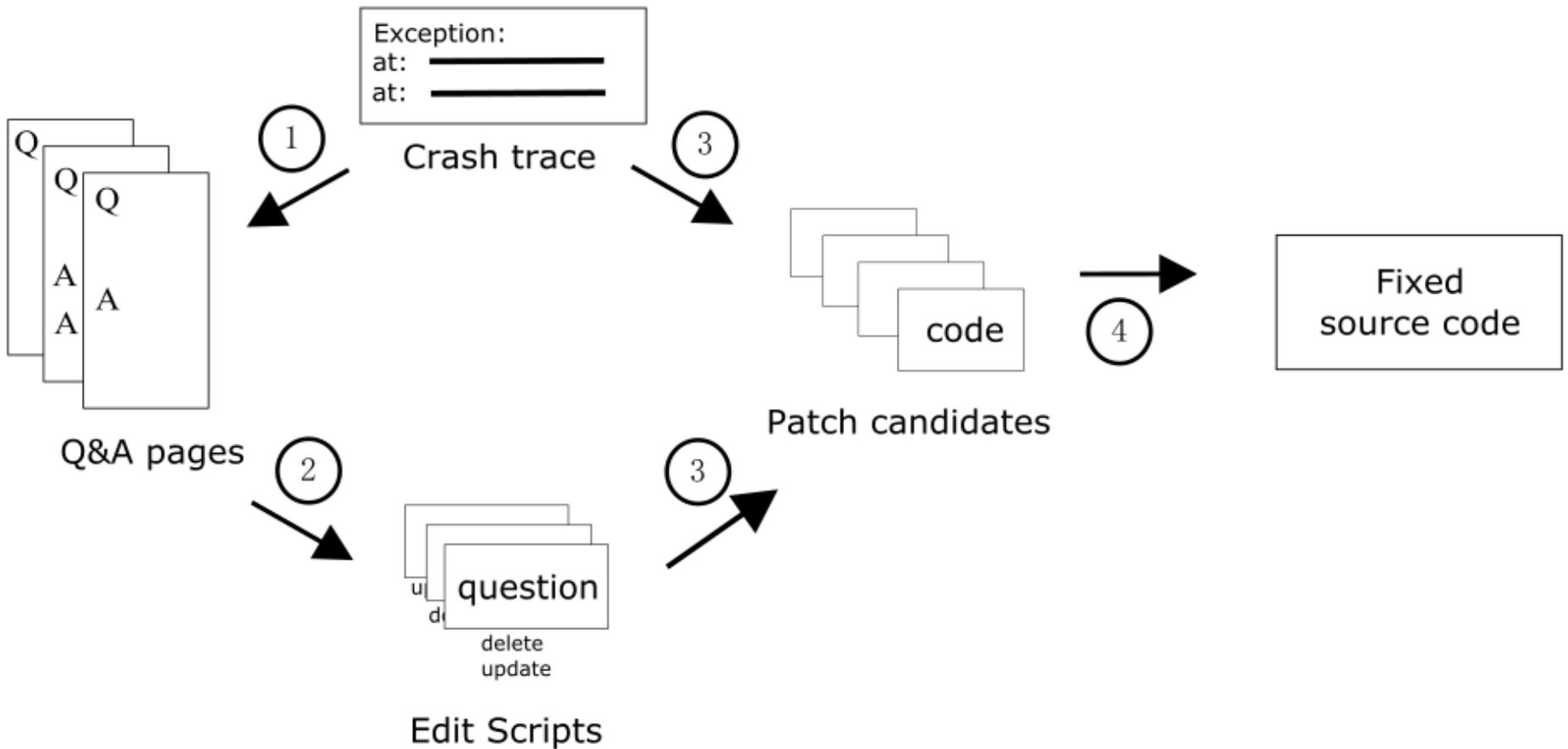


我们的工作

- 主要思想
 - 自动化这个过程
 - 使用因特网资源（问答网站）来修复崩溃缺陷
- 核心
 - 使用代码分析而不是复杂的自然语言处理

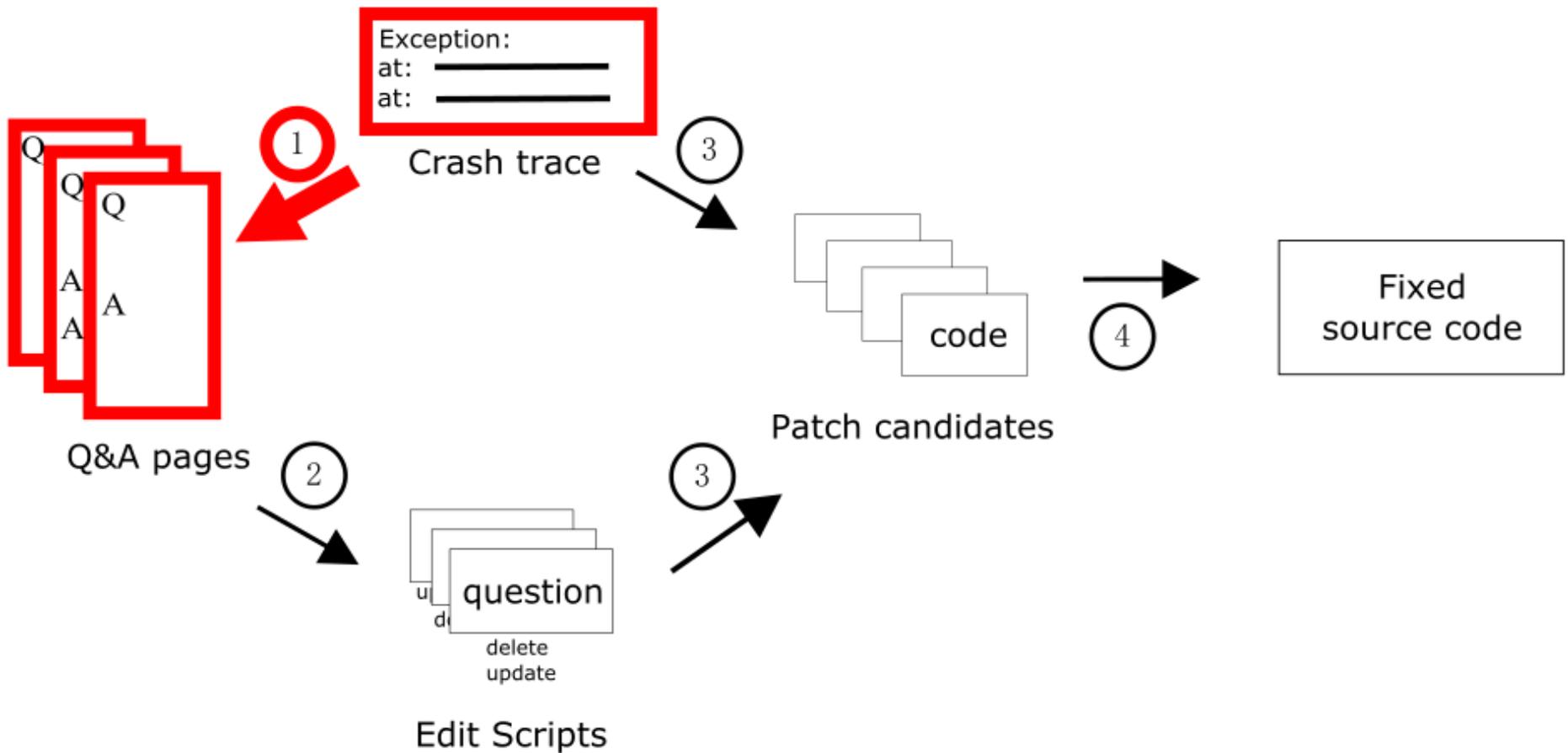


方法概览



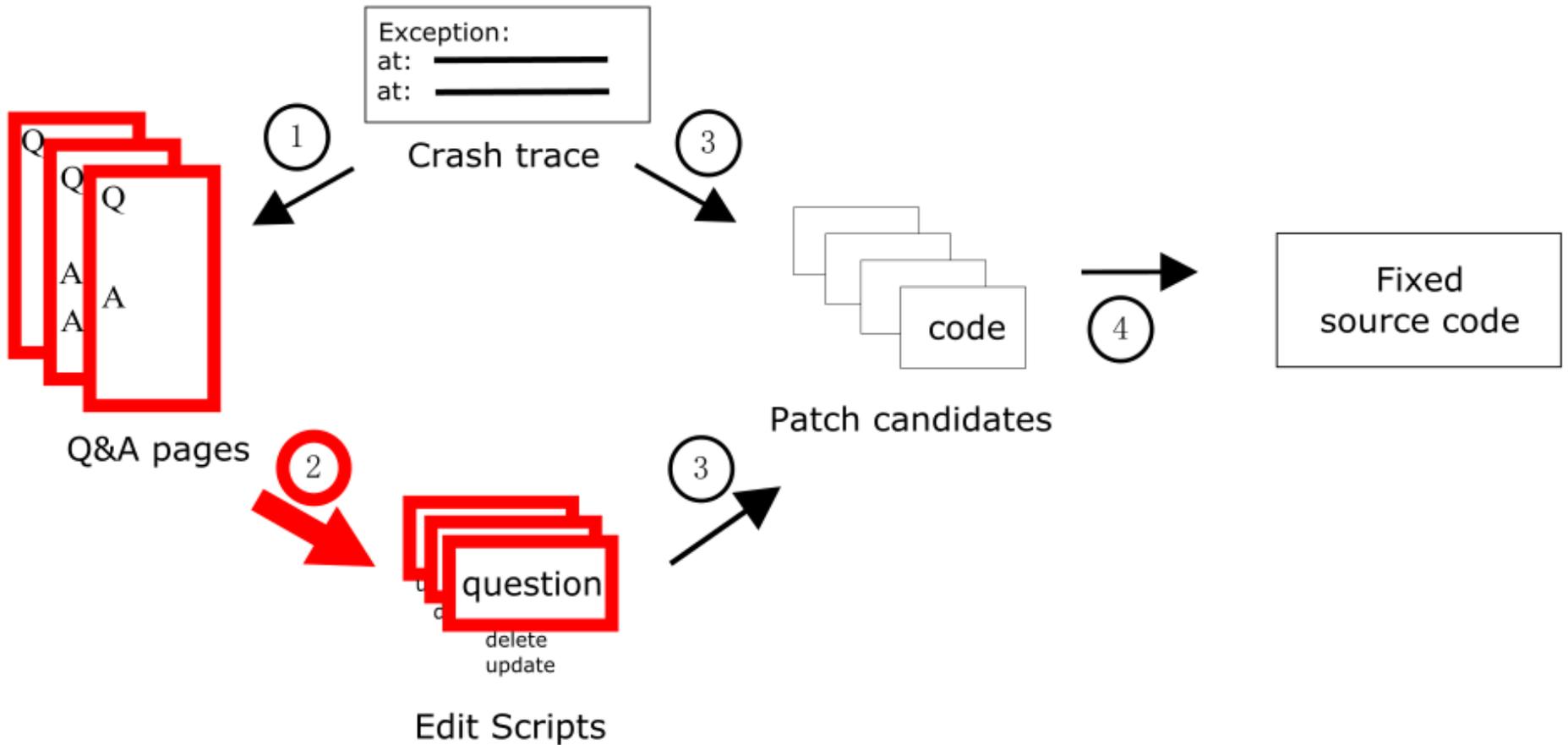


方法概览



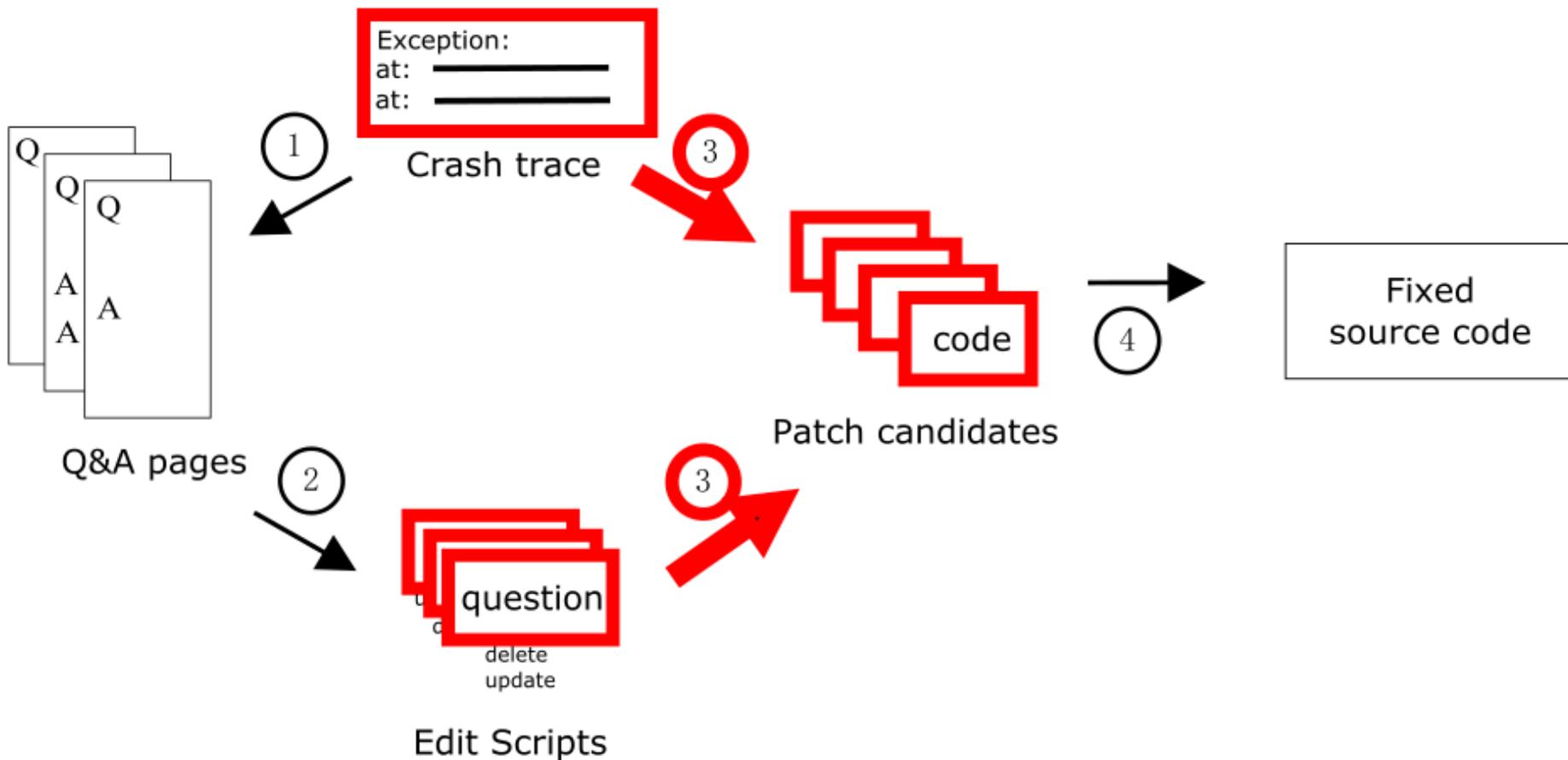


方法概览



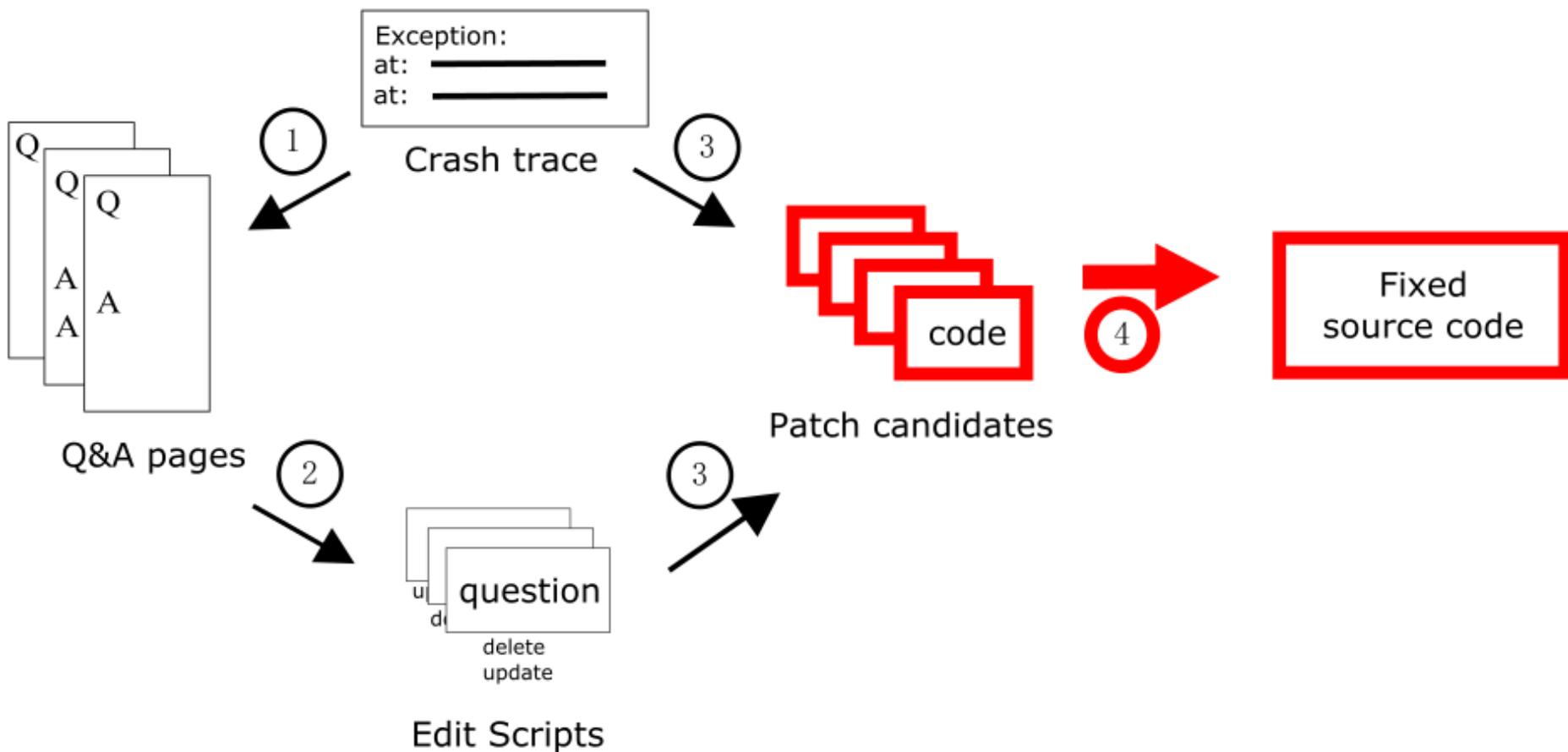


方法概览

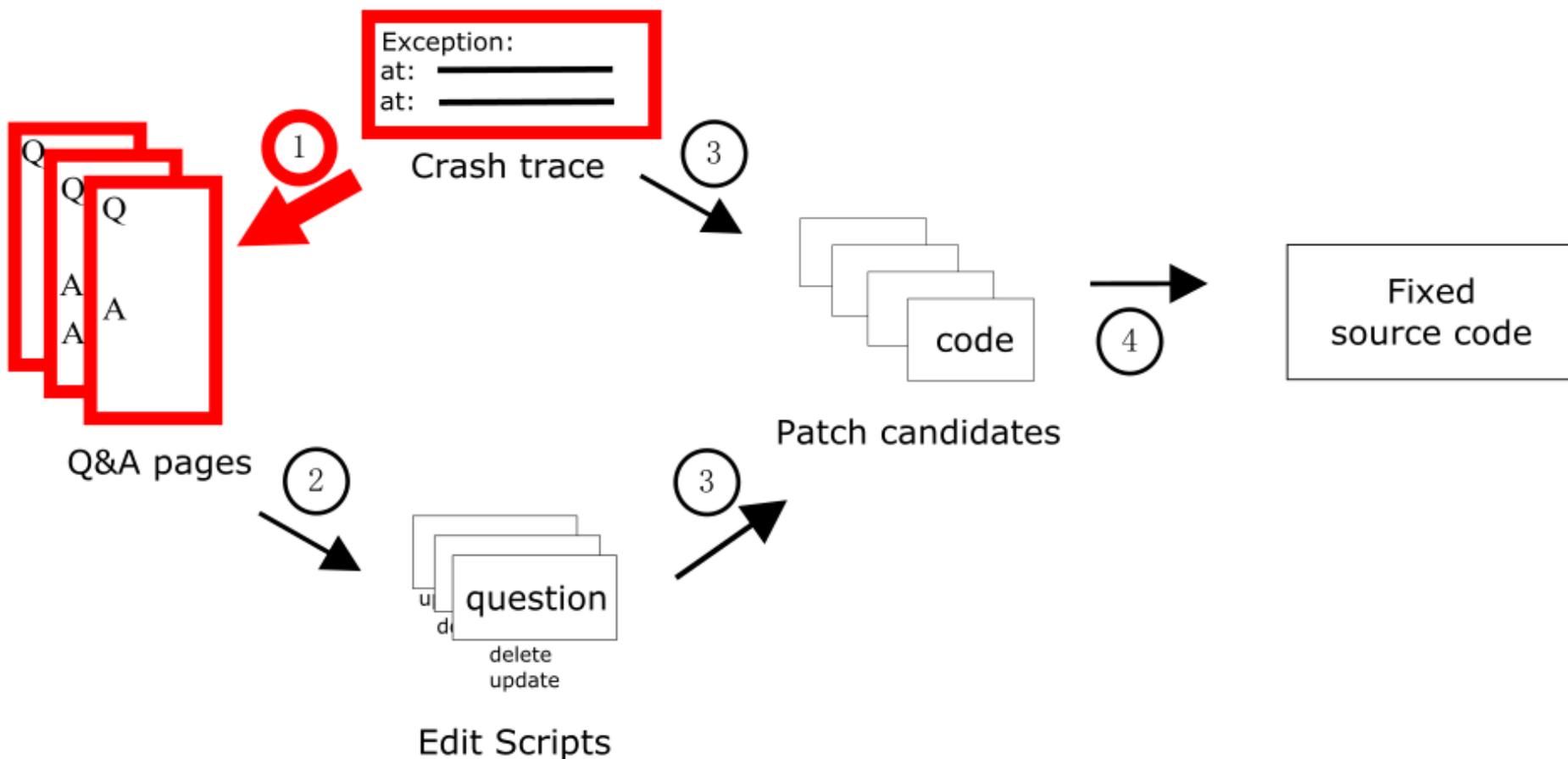




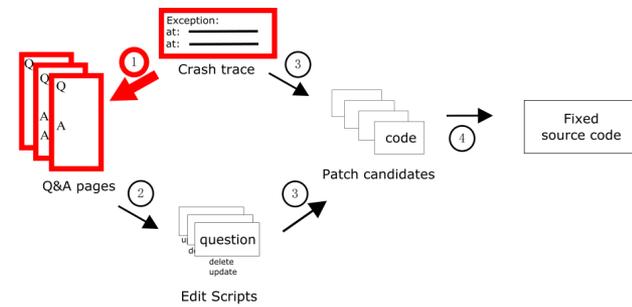
方法概览



步骤1: 提取问答网页



步骤1: 提取问答网页



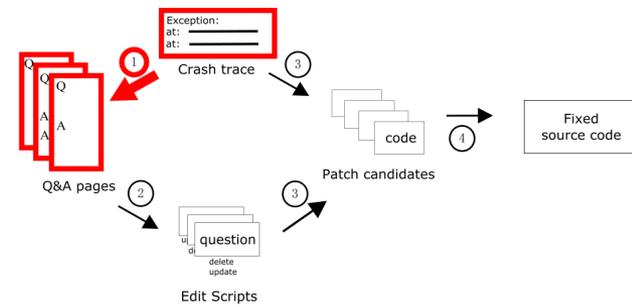
```
29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
```

```
1 java.lang.RuntimeException: Unable to start receiver com.vaguehope.onosendai.update.AlarmReceiver:
  android.content.ReceiverCallNotAllowedException: IntentReceiver components are not allowed to receive intents
```

```
2 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2126)
3 at android.app.ActivityThread.access$1500(ActivityThread.java:123)
4 at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1197)
5 at android.os.Handler.dispatchMessage(Handler.java:99)
6 at android.os.Looper.loop(Looper.java:137)
7 at android.app.ActivityThread.main(ActivityThread.java:4424)
8 at java.lang.reflect.Method.invokeNative(Native Method)
9 at java.lang.reflect.Method.invoke(Method.java:511)
10 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:784)
11 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:551)
12 at dalvik.system.NativeStart.main(Native Method)
```

```
13 Caused by: android.content.ReceiverCallNotAllowedException: IntentReceiver components are not allowed to receive
14 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:118)
15 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:112)
16 at com.vaguehope.onosendai.update.AlarmReceiver.onReceive(AlarmReceiver.java:31)
17 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2119)
18 ... 10 more
```

步骤1: 提取问答网页



```
29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
```

```
1 java.lang.RuntimeException: Unable to start receiver com.vaguehope.onosendai.update.AlarmReceiver:
  android.content.ReceiverCallNotAllowedException: IntentReceiver components are not allowed to receive intents
```

```
2 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2126)
```

```
3 at android.app.ActivityThread.access$1500(ActivityThread.java:123)
```

```
4 at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1197)
```

```
5 at android.os.Handler.dispatchMessage(Handler.java:102)
```

```
6 at android.os.Looper.loop(Looper.java:137)
```

```
7 at android.app.ActivityThread.main(ActivityThread.java:6040)
```

```
8 at java.lang.reflect.Method.invokeNative(Method.java:662)
```

```
9 at java.lang.reflect.Method.invoke(Method.java:513)
```

```
10 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:866)
```

```
11 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:623)
```

```
12 at dalvik.system.NativeStart.main(Native Method)
```

```
13 Caused by: android.content.ReceiverCallNotAllowedException: IntentReceiver components are not allowed to receive intents
```

```
14 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:118)
```

```
15 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:112)
```

```
16 at com.vaguehope.onosendai.update.AlarmReceiver.onReceive(AlarmReceiver.java:29)
```

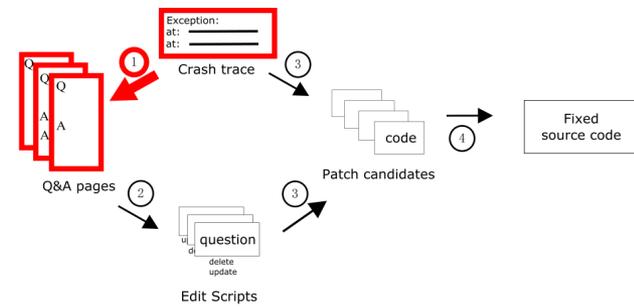
```
17 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2126)
```

```
18 ... 10 more
```

**java.lang.RuntimeException: Unable to start receiver
com.vaguehope.onosendai.update.AlarmReceiver:
android.content.ReceiverCallNotAllowedException:
IntentReceiver components
are not allowed to register to receive intents**

Search Engine

步骤1: 提取问答网页



java.lang.RuntimeException: Unable to start receiver com.vaguehope.ono



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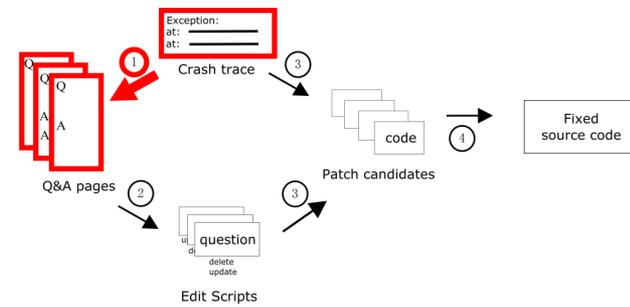
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Your search - **java.lang.RuntimeException: Unable to start receiver com.vaguehope.onosendai.update ...** - did not match any documents.

Suggestions:

- Make sure that all words are spelled correctly.
- Try different keywords.
- Try more general keywords.
- Try fewer keywords.

步骤1: 提取问答网页



```
29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
33     switch (action) {
```

```
1 java.lang.RuntimeException: Unable to start receiver com.vaguehope.onosendai.update.AlarmReceiver:
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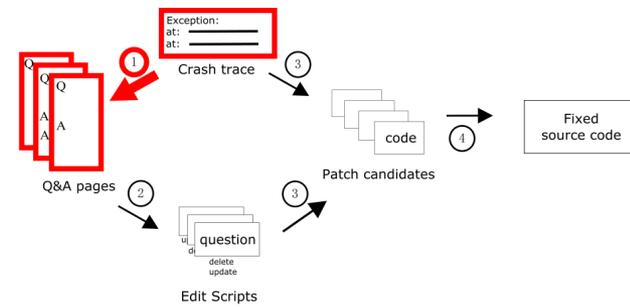
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4 at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1197)
5 at android.os.Handler.dispatchMessage(Handler.java:106)
6 at android.os.Looper.loop(Looper.java:137)
7 at android.app.ActivityThread.main(ActivityThread.java:6040)
8 at java.lang.reflect.Method.invokeNative(Method.java:662)
9 at java.lang.reflect.Method.invoke(Method.java:513)
10 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:210)
11 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:343)
12 at dalvik.system.NativeStart.main(Native Method)
```

**java.lang.RuntimeException: Unable to start receiver
com.vaguehope.onosendai.update.AlarmReceiver:
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16 at com.vaguehope.onosendai.update.AlarmReceiver.onReceive(ContextImpl.java:112)
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18 ... 10 more
```

搜索引擎

步骤1: 提取问答网页



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29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
33     switch (action) {
```

```
1 java.lang.RuntimeException: Unable to start receiver com.vaguehope.onosendai.update.AlarmReceiver:
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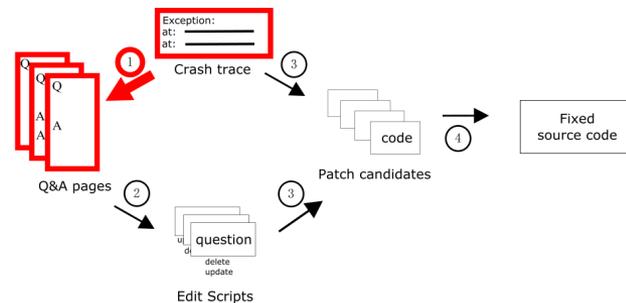
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2 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2126)
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4 at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1197)
5 at android.os.Handler.dispatchMessage(Handler.java:106)
6 at android.os.Looper.loop(Looper.java:137)
7 at android.app.ActivityThread.main(ActivityThread.java:6040)
8 at java.lang.reflect.Method.invokeNative(Method.java:662)
9 at java.lang.reflect.Method.invoke(Method.java:500)
10 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:858)
11 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:644)
12 at dalvik.system.NativeStart.main(Native Method)
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16 at com.vaguehope.onosendai.update.AlarmReceiver.onReceive(ContextImpl.java:112)
17 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2126)
18 ... 10 more
```

搜索引擎

步骤1: 提取问答网页



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29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
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```
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```

```
3 at android.app.ActivityThread.access$1500(ActivityThread.java:123)
```

```
4 at android.app.ActivityThread$H.handleMessage(ActivityThread.java:1197)
```

```
5 at android.os.Handler.dispatchMessage(Handler.java:105)
```

```
6 at android.os.Looper.loop(Looper.java:137)
```

```
7 at android.app.ActivityThread.main(ActivityThread.java:6013)
```

```
8 at java.lang.reflect.Method.invokeNative(Method.java:662)
```

```
9 at java.lang.reflect.Method.invoke(Method.java:513)
```

```
10 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:819)
```

```
11 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:601)
```

```
12 at dalvik.system.NativeStart.main(Native Method)
```

```
13 Caused by: android.content.ReceiverCallNotAllowedException: IntentReceiver components are not allowed to receive intents
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```
14 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:118)
```

```
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```
16 at com.vaguehope.onosendai.update.AlarmReceiver.onReceive(AlarmReceiver.java:29)
```

```
17 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2126)
```

```
18 ... 10 more
```

```
java.lang.RuntimeException: Unable to start receiver
com.vaguehope.onosendai.update.AlarmReceiver:
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```

搜索引擎

java.lang.RuntimeException: Unable to start receiver : android.conten

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Jul 24, 2014 - "IntentReceiver components are not allowed to register to receive ...
ACTION_BATTERY_CHANGED); Intent batteryStatus = c. ... RuntimeException: Unable to start receiver ...
ActivityThread.main(ActivityThread.java:4627) at java.lang.reflect. ... NativeStart.main(Native Method) Caused by: android.content.

android - Battery changed broadcast receiver crashing app ...
stackoverflow.com/.../battery-changed-broadcast-receiver-crashing-app-...
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... PowerConnectionReceiver"> <intent-filter> <action android:name="android.intent
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"IntentReceiver components are not allowed to register to receive intents to determine Battery level"



I am trying to get Battery info from my Application following the guidelines at <http://developer.android.com/training/monitoring-device-state/battery-monitoring.html>

This is the method I came up with to check the battery level:

```
public void sendBatteryInfoMessage(){  
  
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_CHANGED);  
    Intent batteryStatus = c.registerReceiver(null, iFilter);
```

```
java.lang.RuntimeException: Unable to start receiver wifi.myapp.sudara.lk.sudara_app.Sm  
at android.app.ActivityThread.handleReceiver(ActivityThread.java:2821)  
at android.app.ActivityThread.access$3200(ActivityThread.java:125)  
at android.app.ActivityThread$H.handleMessage(ActivityThread.java:2083)  
at android.os.Handler.dispatchMessage(Handler.java:99)  
at android.os.Looper.loop(Looper.java:123)  
at android.app.ActivityThread.main(ActivityThread.java:4627)
```

Instead of:

```
context.registerReceiver(null, new IntentFilter(Intent.ACTION_BATTERY_CHANGED));
```

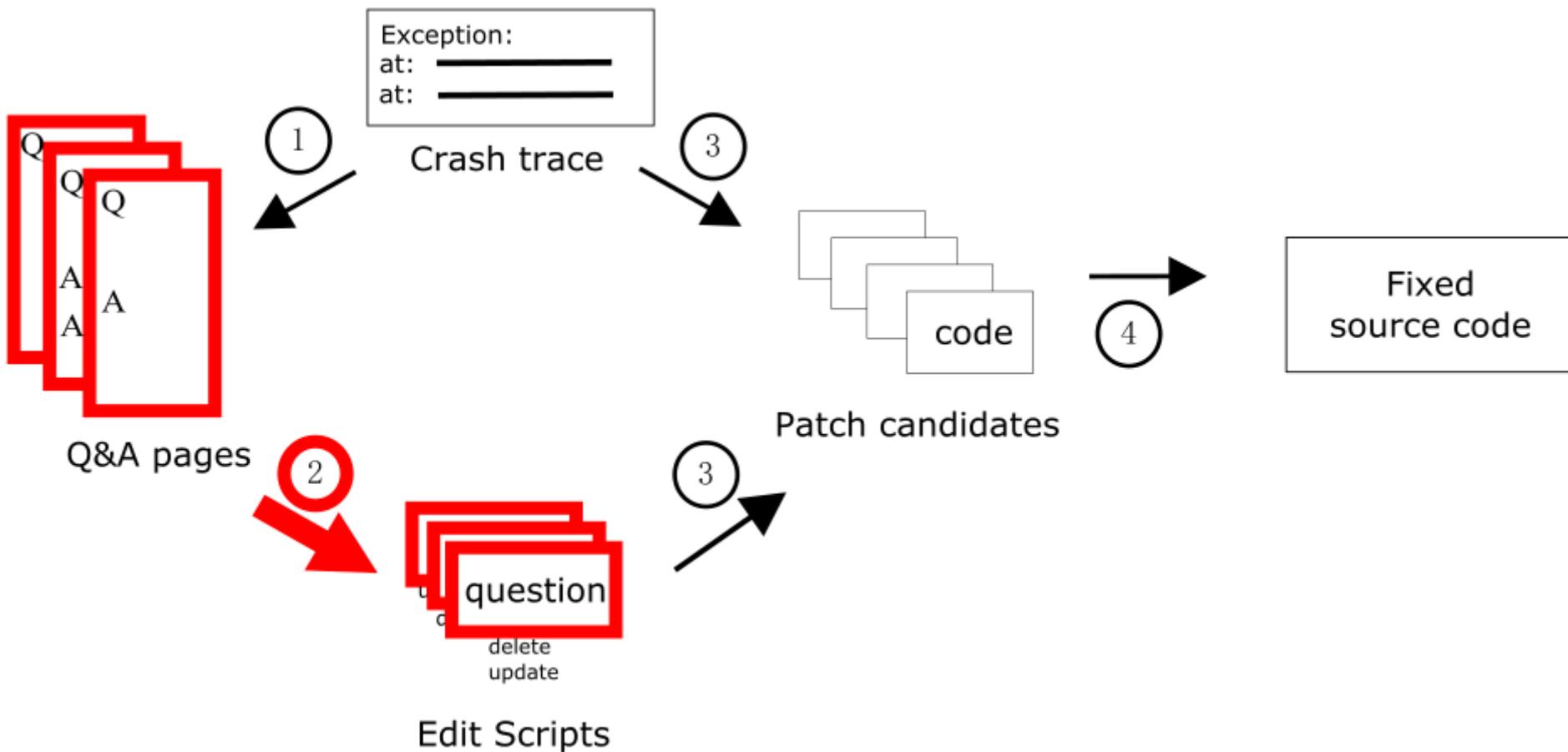
use:

```
context.getApplicationContext().registerReceiver(null, new IntentFilter(Intent.ACTION_BATTERY_CHANGED));
```

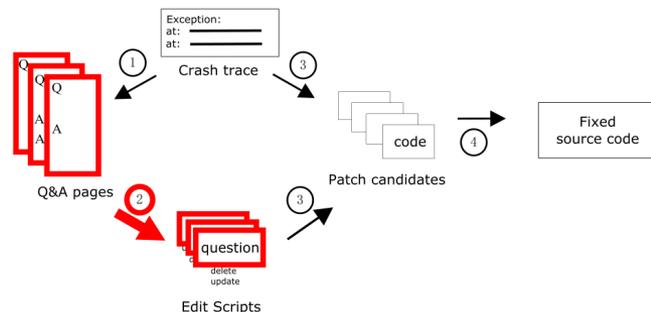
This is annoying -- registerReceiver() should be smarter than this -- but it's the workaround for this particular case.



步骤2: 生成编辑脚本



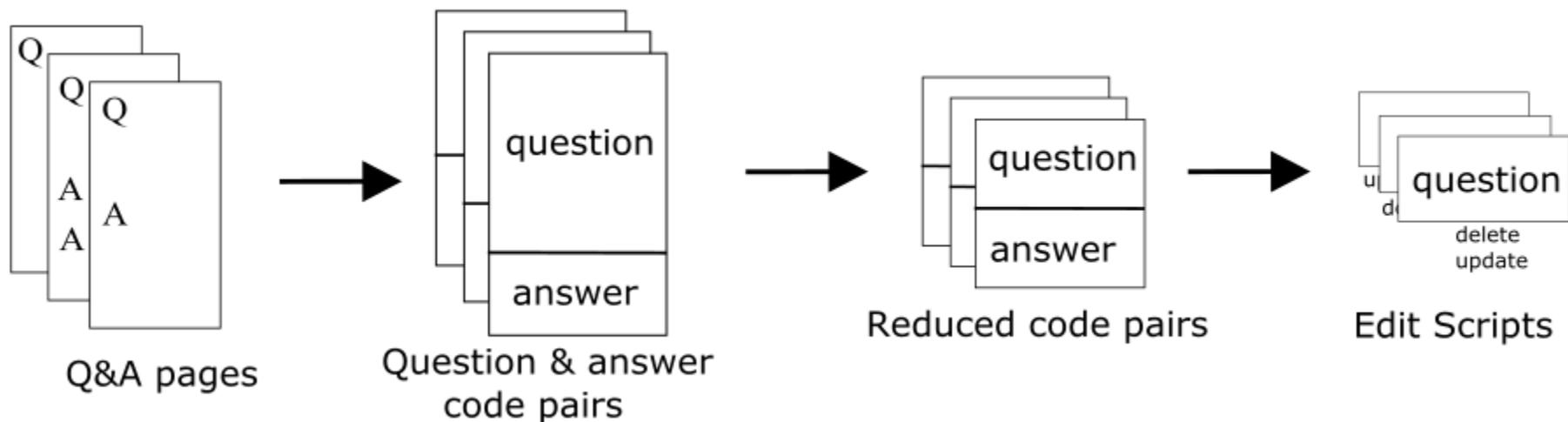
步骤2: 生成编辑脚本



- 核心组件

- 代码对

问题代码: 问答网站中的错误代码
答案代码: 问答网站中的修复代码



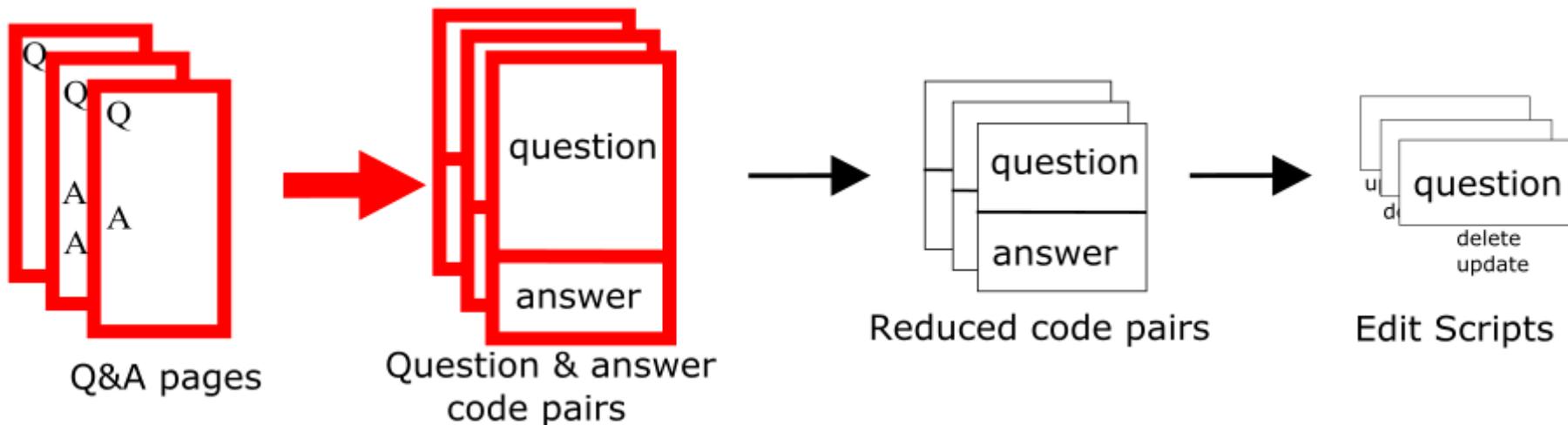
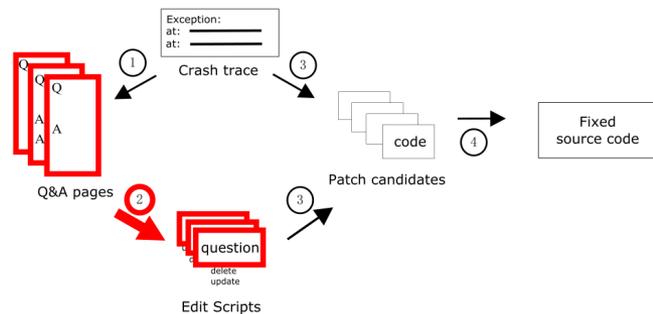
步骤2: 生成编辑脚本

- 核心组件

- 代码对

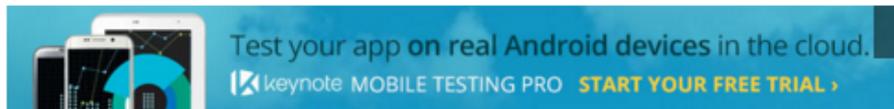
问题代码: 问答网站中的错误代码

答案代码: 问答网站中的修复代码



Stack Overflow is a community of 4.7 million programmers, just like you, helping each other only takes a minute:

"IntentReceiver components are not allowed to register to receive inter determine Battery level



I am trying to get Battery info from my Application following the guidelines at <http://developer.android.com/training/monitoring-device-state/battery-monitoring.html>

This is the method is came up with to check the battery level:

```
public void sendBatteryInfoMessage(){
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_
    Intent batteryStatus = c.registerReceiver(null, iFilter);
}
```

A

Instead of:

```
context.registerReceiver(null, new IntentFilter(Intent.ACTION_BATTERY_CHANGED));
```

B

use:

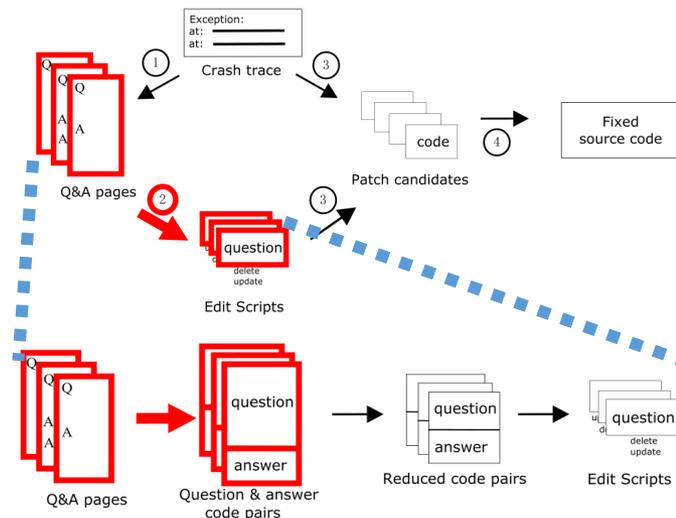
```
context.getApplicationContext().registerReceiver(null, new IntentFilter(Intent.ACTION_BATTER
```

C

This is annoying -- registerReceiver() should be smarter than this -- but it's the workaround for this particular case.

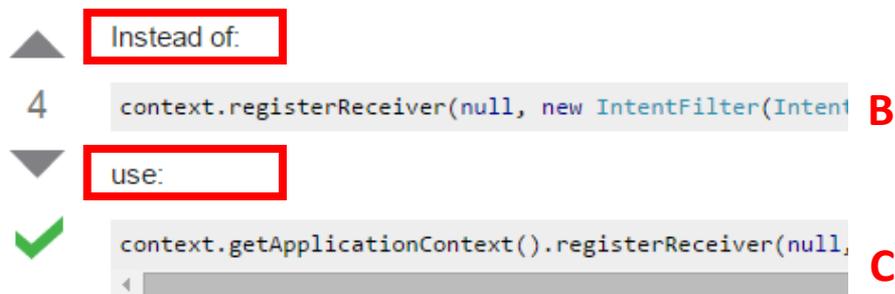
share improve this answer

answered Jun 29 '12 at 19:57
 CommonsWare
 510k ● 60 ● 1155 ● 1221

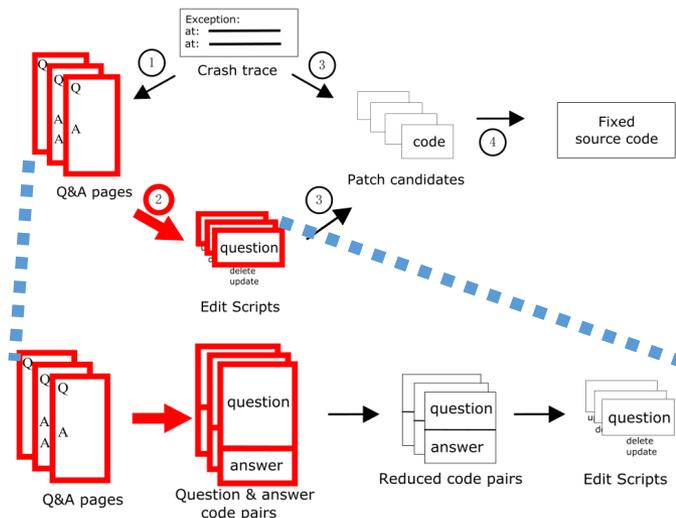


把代码片段组合为代码对

- 两段代码都从答案帖中提取



- 分别从问题帖和答案帖中提取



```
public void sendBatteryInfoMessage(){  
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_CHANGED);  
    Intent batteryStatus = c.registerReceiver(null, iFilter);  
  
    int status = batteryStatus.getIntExtra(BatteryManager.EXTRA_STATUS, -1);  
    boolean isCharging = status == BatteryManager.BATTERY_STATUS_CHARGING || status == BatterieManager.BATTERY_STATUS_CHARGING_DISCONNECTED;  
  
    int chargePlug = batteryStatus.getIntExtra(BatteryManager.EXTRA_PLUGGED, -1);  
    boolean isUsbCharge = chargePlug == BatteryManager.BATTERY_PLUGGED_USB;  
    boolean isAcCharge = chargePlug == BatteryManager.BATTERY_PLUGGED_AC;  
  
    int batteryLevel = batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);  
    int scale = batteryStatus.getIntExtra(BatteryManager.EXTRA_SCALE, -1);  
  
    float batteryPct = batteryLevel / (float) scale;  
}
```

A **A**

B **C**

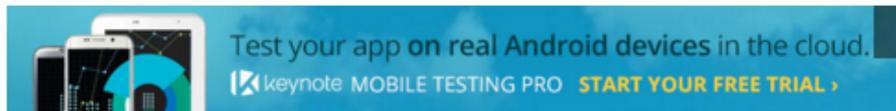
```
public void sendBatteryInfoMessage(){  
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_CHANGED);  
    Intent batteryStatus = c.registerReceiver(null, iFilter);  
  
    int status = batteryStatus.getIntExtra(BatteryManager.EXTRA_STATUS, -1);  
    boolean isCharging = status == BatteryManager.BATTERY_STATUS_CHARGING || status == BatterieManager.BATTERY_STATUS_CHARGING_DISCONNECTED;  
  
    int chargePlug = batteryStatus.getIntExtra(BatteryManager.EXTRA_PLUGGED, -1);  
    boolean isUsbCharge = chargePlug == BatteryManager.BATTERY_PLUGGED_USB;  
    boolean isAcCharge = chargePlug == BatteryManager.BATTERY_PLUGGED_AC;  
  
    int batteryLevel = batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);  
    int scale = batteryStatus.getIntExtra(BatteryManager.EXTRA_SCALE, -1);  
  
    float batteryPct = batteryLevel / (float) scale;  
}
```

A **A**

B **C**

Stack Overflow is a community of 4.7 million programmers, just like you, helping each other only takes a minute:

"IntentReceiver components are not allowed to register to receive inter determine Battery level

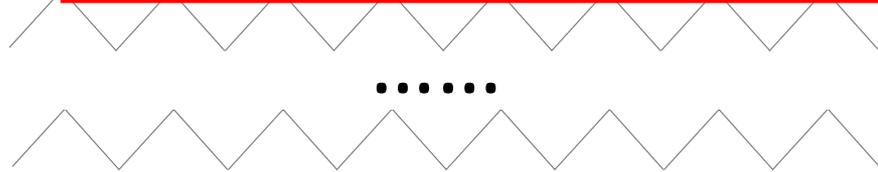


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This is the method is came up with to check the battery level:

```
public void sendBatteryInfoMessage(){
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_
    Intent batteryStatus = c.registerReceiver(null, iFilter);
}
```

A



Instead of:

```
context.registerReceiver(null, new IntentFilter(Intent.ACTION_BATTERY_CHANGED));
```

B

use:

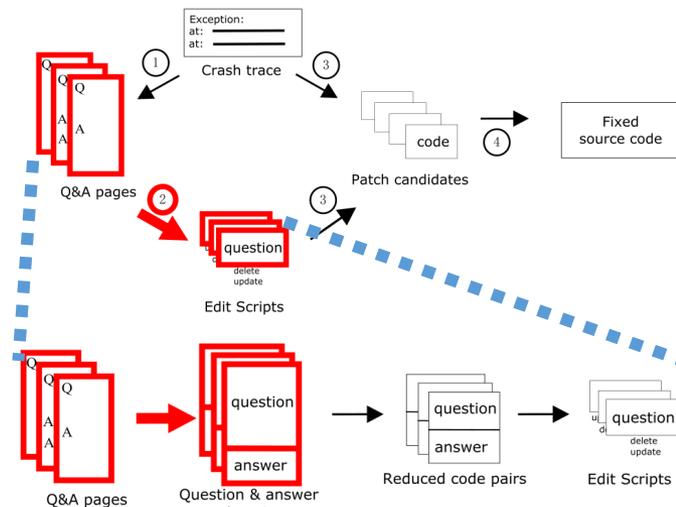
```
context.getApplicationContext().registerReceiver(null, new IntentFilter(Intent.ACTION_BATTER
```

C

This is annoying -- registerReceiver() should be smarter than this -- but it's the workaround for this particular case.

share improve this answer

answered Jun 29 '12 at 19:57
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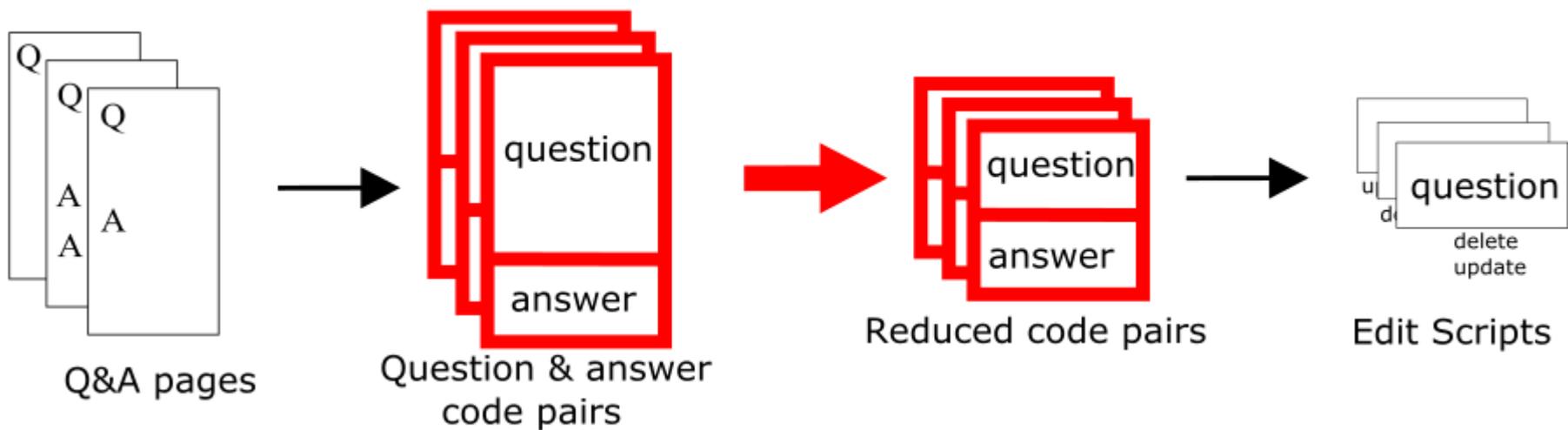
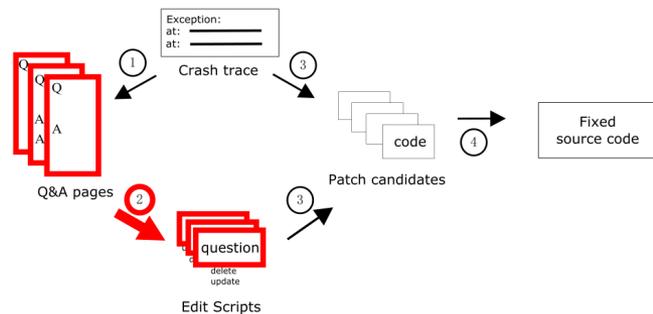
• B | C

• A | B

• A | C

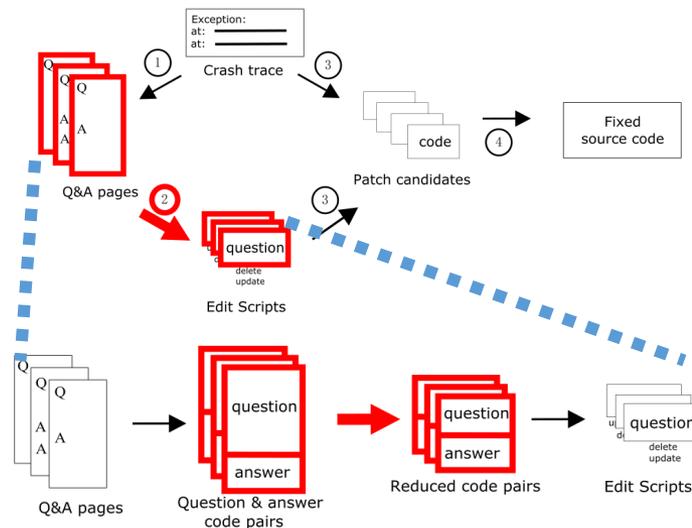
步骤2: 生成编辑脚本

- 核心组件
 - 代码对



减少代码对:

- 文本相似度
- 结构相似度



```
public void sendBatteryInfoMessage(){  
  
    IntentFilter iFilter = new IntentFilter(Intent.ACTION_BATTERY_CHANGED);  
    Intent batteryStatus = c.registerReceiver(null, iFilter);  
  
    int status = batteryStatus.getIntExtra(BatteryManager.EXTRA_STATUS, -1);  
    boolean isCharging = status == BatteryManager.BATTERY_STATUS_CHARGING || status == Batterie  
  
    int chargePlug = batteryStatus.getIntExtra(BatteryManager.EXTRA_PLUGGED, -1);  
    boolean isUsbCharge = chargePlug == BatteryManager.BATTERY_PLUGGED_USB;  
    boolean isAcCharge = chargePlug == BatteryManager.BATTERY_PLUGGED_AC;  
  
    int batteryLevel = batteryStatus.getIntExtra(BatteryManager.EXTRA_LEVEL, -1);  
    int scale = batteryStatus.getIntExtra(BatteryManager.EXTRA_SCALE, -1);  
  
    float batteryPct = batteryLevel / (float) scale;  
  
}
```

A

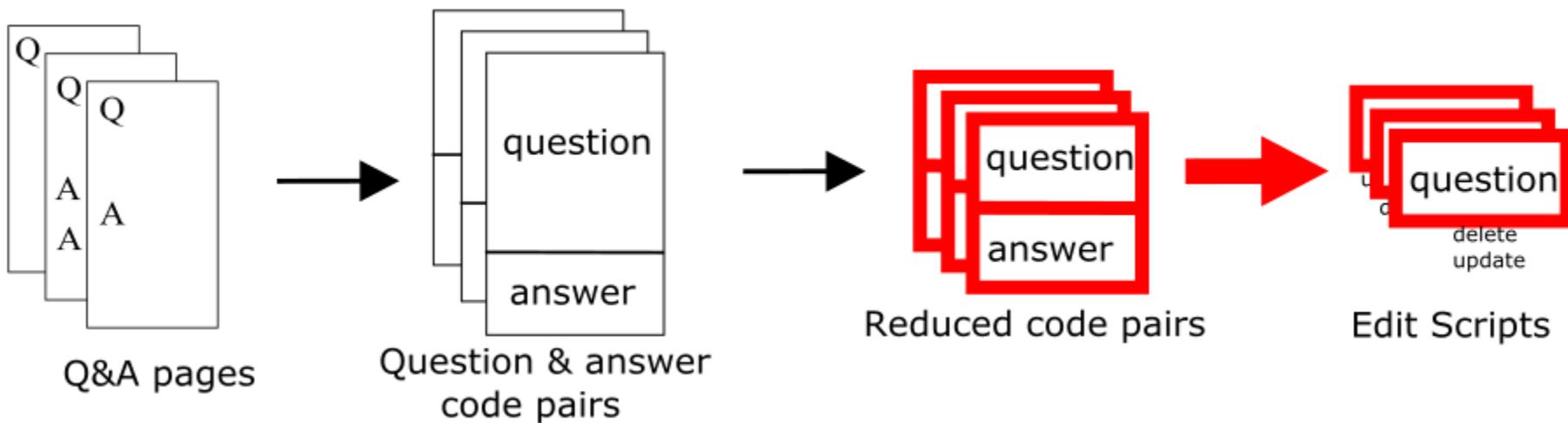
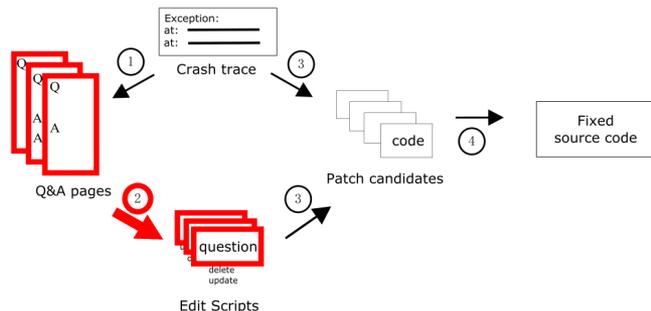
```
B context.getApplicationContext().registerReceiver(nu
```



```
Intent intent = context.registerReceiver(...);  
-----  
context.getApplicationContext().registerReceiver(...);
```

步骤2: 生成编辑脚本

- 核心组件
 - 代码对



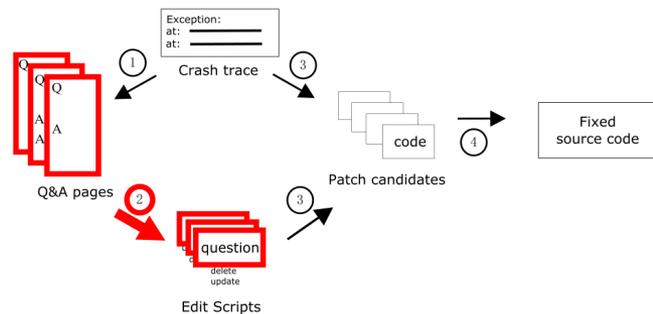
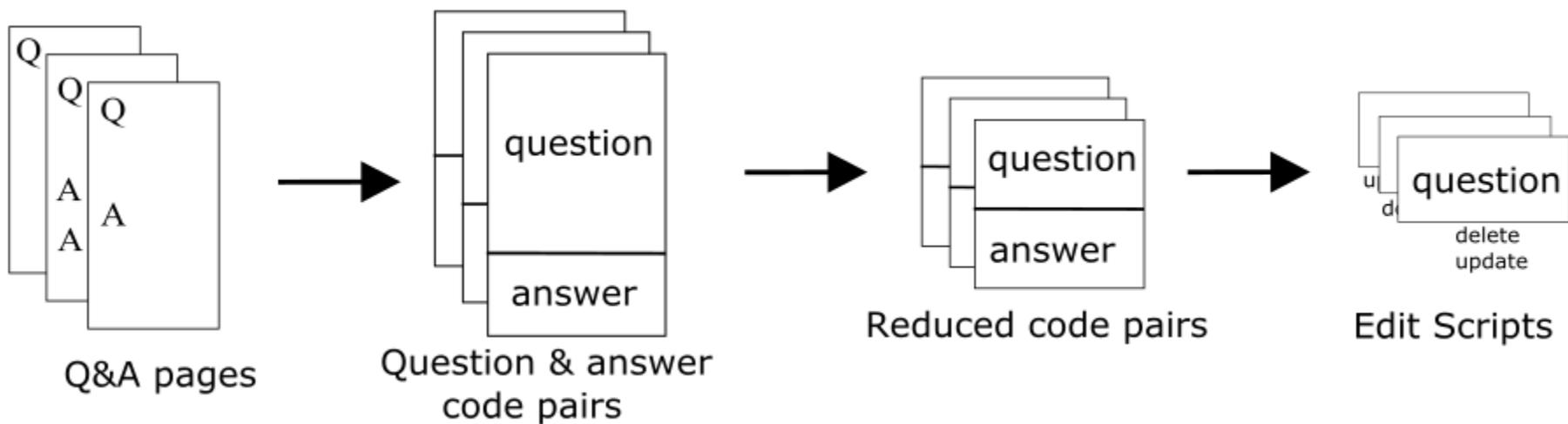
- 现有的编辑脚本生成算法- GumTree

1st position **Insert getContext() after 1st position**

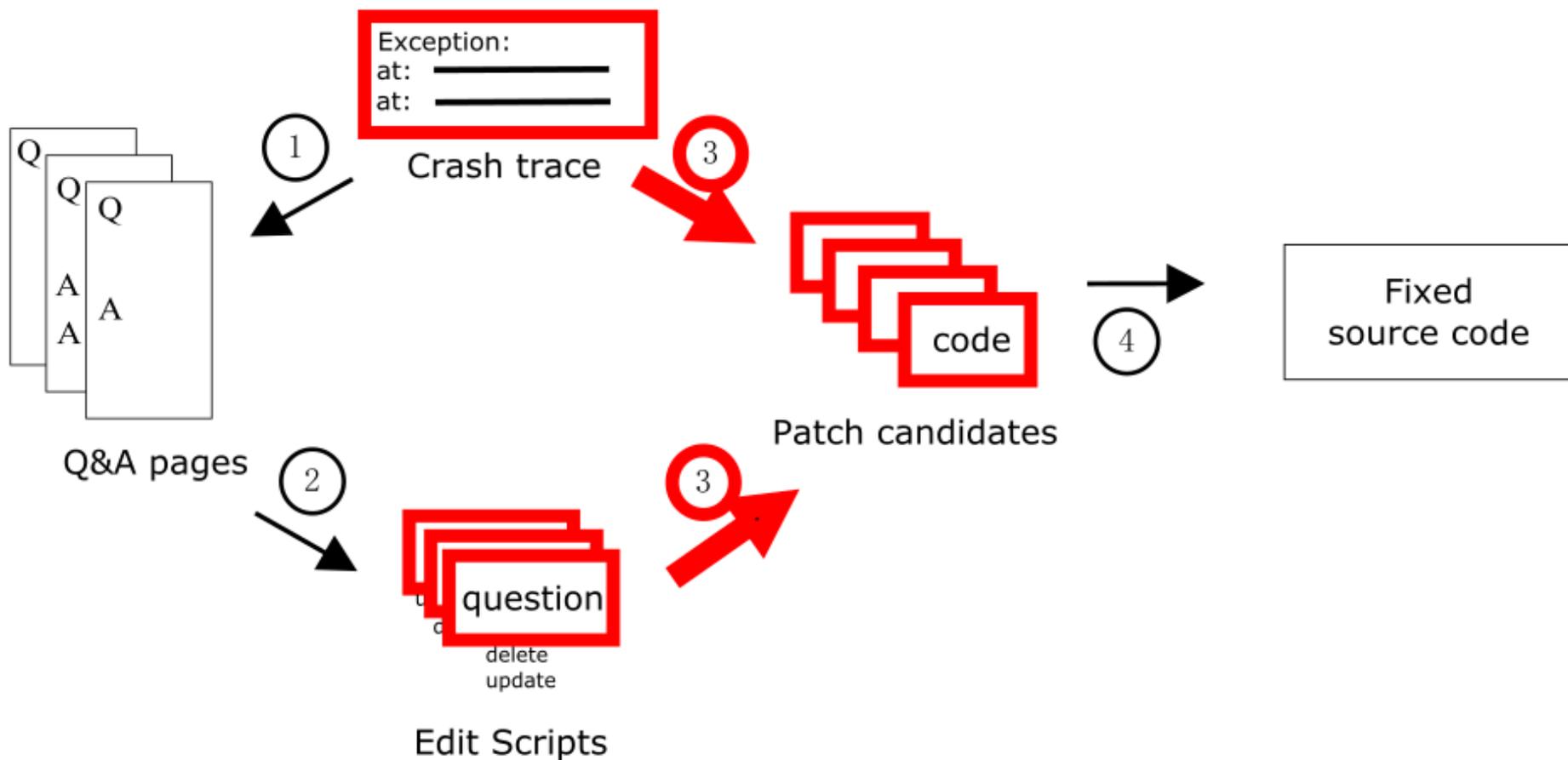
```
context.registerReceiver(...);  
context.getContext()registerReceiver(...);
```

步骤2: 生成编辑脚本

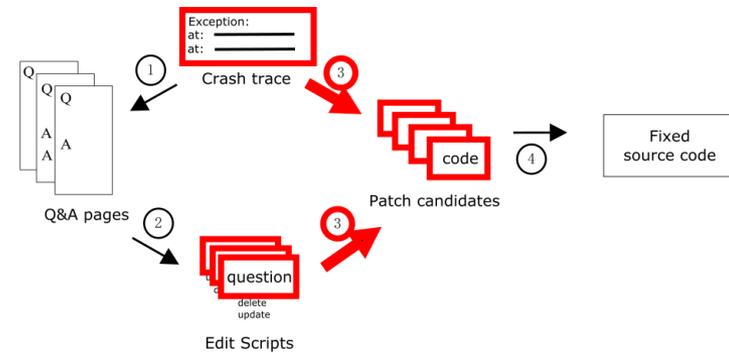
- 核心组件
 - 代码对



步骤3: 生成补丁



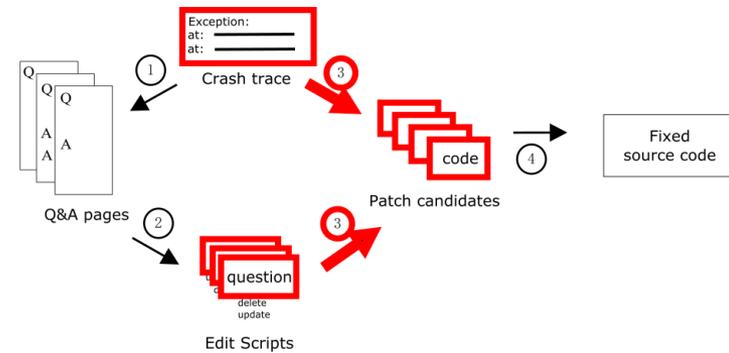
步骤3: 生成补丁



```
10 at com.android.internal.os.ZygoteInit$MethodAndArgsCaller.run(ZygoteInit.java:784)
11 at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:551)
12 at dalvik.system.NativeStart.main(Native Method)
13 Caused by: android.content.ReceiverCallNotAllowedException: IntentReceiver compor
14 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:118)
15 at android.app.ReceiverRestrictedContext.registerReceiver(ContextImpl.java:112)
16 at com.vaguehope.onosendai.update.AlarmReceiver.onReceive(AlarmReceiver.java:31)
17 at android.app.ActivityThread.handleReceiver(ActivityThread.java:2119)
18 ... 10 more
```

```
29 public void onReceive (final Context context, final Intent intent) {
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);
31     final float bl = BatteryHelper.level(context);
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);
33     switch (action) {
34         ...
35         ...
36     }
37 }
38 }
```

步骤3: 生成补丁



```
t.ReceiverCallNotAllowedException: IntentReceiver compo  
strictedContext.registerReceiver(ContextImpl.java:118)  
strictedContext.registerReceiver(ContextImpl.java:112)  
ai.update.AlarmReceiver.onReceive(AlarmReceiver.java:31)  
ad.handleReceiver(ActivityThread.java:2119)
```

```
context.registerReceiver(null, new I
```

```
29 public void onReceive (final Context context, final Intent intent) {  
30     final int action = intent.getExtras().getInt(KEY_ACTION, -1);  
31     final float bl = BatteryHelper.level(context);  
32     LOG.i("AlarmReceiver invoked: action=%s bl=%s.", action, bl);  
33     switch (action) {  
...     ...  
51     }  
52 }
```



步骤3: 生成补丁

- 编辑脚本
 - 把一个代码片段变换为另一个代码片段
- 改变的位置
- 重命名的变量



改变的位置

问题代码

```
context.registerReceiver(...);  
1st position
```

编辑脚本:

Insert `getApplicationContext()`
after **1st position**

答案代码

```
context.getApplicationContext().registerReceiver(...);
```

缺陷代码

```
BatteryHelper.level(context);  
1st position    2nd position
```

3rd position

编辑脚本:

Insert `getApplicationContext()`
after **3rd position**

```
BatteryHelper.level(context).  
↓  
BatteryHelper.level(context)..getApplicationContext());
```



重命名的变量

问题代码

```
a = 1;
```

答案代码

```
a = a + 1;
```

缺陷代码

```
c = 1;
```

```
c = c + 1;
```



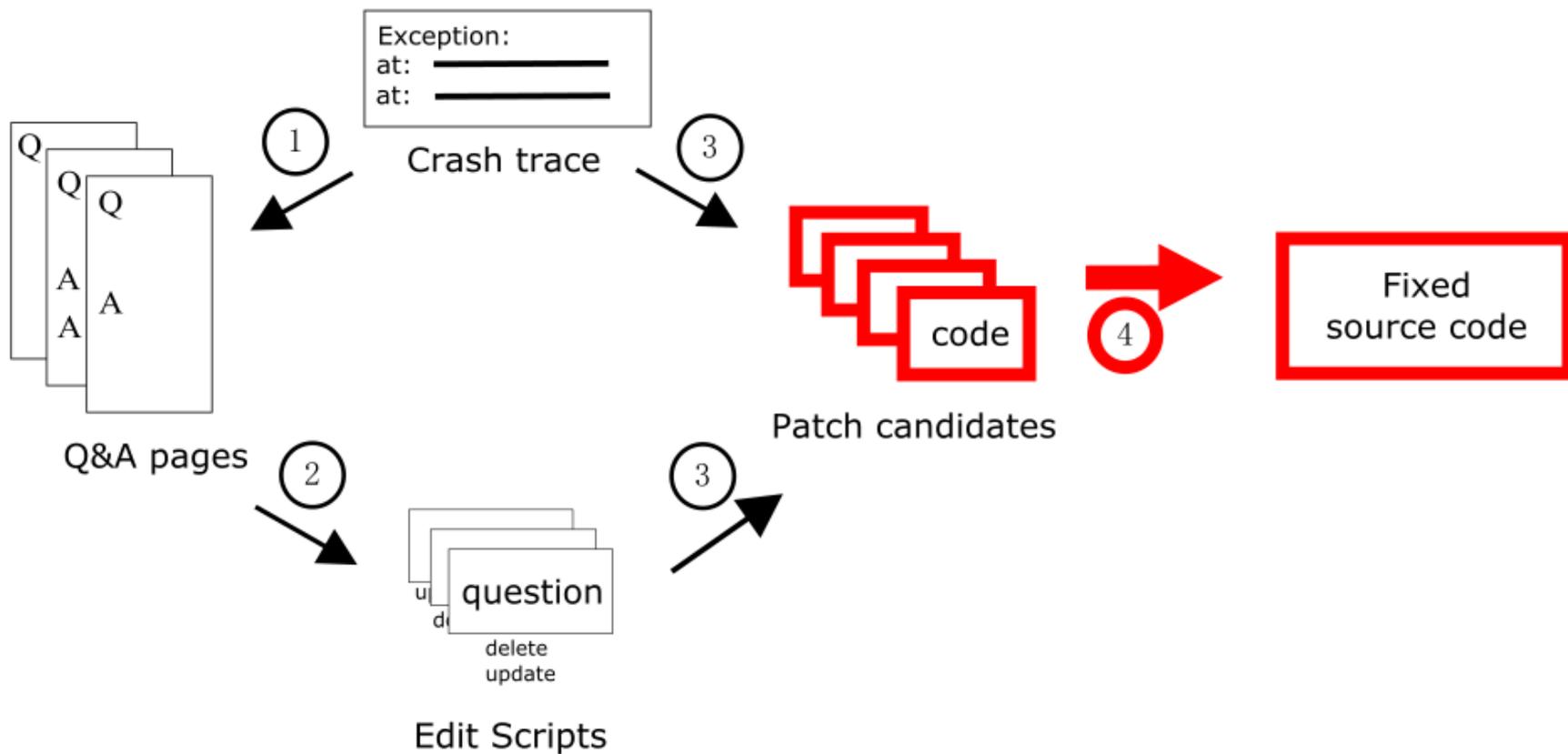
编辑脚本:

Insert 'a' and '+'

编辑脚本:

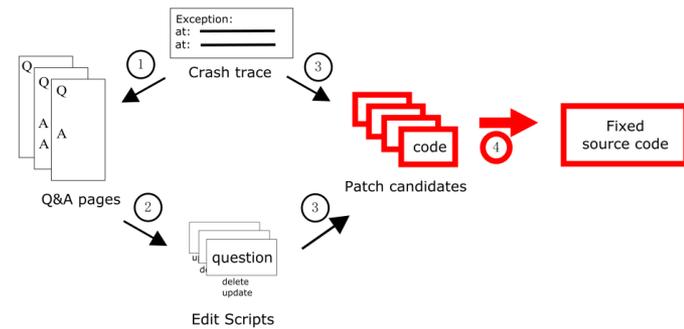
Insert 'c' and '+'

步骤4: 过滤补丁



步骤4: 过滤补丁

- 合并等价补丁
- 过滤掉不能通过编译的补丁
- 取出前k个补丁
 - k=1





实验

- RQ1:有效性
 - 我们的方法在修复真实世界的复发缺陷上有效性有多高??
- RQ2:有用性
 - 我们的方法是否能补充现有的修复方法?



实验

- 实验对象: GitHub项目
- 复发缺陷: 24
 - Android工程
 - 崩溃踪迹
 - 人工写出的补丁
 - 解决方案在因特网中已经存在
- 开源工具
 - <http://sei.pku.edu.cn/~gaoqing11/qacrashfix>



RQ1 – 有效性

- 24个缺陷中产生了10个(第一个)补丁, 其中8个正确

Project	Issue No.	Loc	#Edit Scripts	#Patches		#Patches Compile Error	Remaining	Correct
				Initial	Equivalent			
Calligraphy	41	406	0	0	0	0	0	-
screen-notifications	23	846	6	1	0	1	0	-
TuCanMobile	27	2,849	8	20	2	12	6	Y
OpenIAB	62	7,053	8	1	0	0	1	Y
Android-Universal-Image-Loader	660	11,829	8	0	0	0	0	-
couchbase-lite-android	292	12,004	5	9	0	9	0	-
Onosendai	100	17,821	6	12	2	3	7	Y
LNReader-Android	62	21,276	3	1	0	0	1	Y
the-blue-alliance-android	252	24,094	5	1	0	1	0	-
open-keychain	217	31,038	9	9	1	6	2	Y
Ushahidi_Android	100	33,574	9	2	0	2	0	-
cgeo	457	36,963	8	11	1	3	7	N
cgeo	887	42,814	8	13	5	6	2	Y
TextSecure	1397	46,469	9	40	0	40	0	-
cgeo	2537	54,765	6	0	0	0	0	-
WordPress-Android	688	62,344	9	8	0	8	0	-
WordPress-Android	780	62,455	0	0	0	0	0	-
WordPress-Android	1320	62,895	9	5	1	3	1	Y
WordPress-Android	1484	65,307	1	0	0	0	0	-
WordPress-Android	1122	65,539	6	0	0	0	0	-
gnucash-android	221	68,158	11	0	0	0	0	-
cgeo	3991	68,202	12	8	0	3	5	Y
WordPress-Android	1928	71,485	8	1	0	0	1	N
calabash-android	149	93,146	10	30	0	30	0	-
Total	-	963,332	164	172	12	127	33	8



RQ1 – 时间开销

- 平均时间:
62.2 s/bug

- 编译时间:
68.5%

- 得到第一个补丁的平均时间:
37.5 s/bug

Project	Issue No.	Loc	Time (sec)		
			First	Total	Compilation
Calligraphy	41	406	0.001	0.001	0
screen-notifications	23	846	30.205	30.205	12.187
TuCanMobile	27	2,849	10.619	83.447	54.866
OpenIAB	62	7,053	37.106	53.433	35.905
Android-Universal-Image-Loader	660	11,829	12.629	12.629	0
couchbase-lite-android	292	12,004	71.361	71.361	52.914
Onosendai	100	17,821	6.845	70.080	62.945
LNReader-Android	62	21,276	13.136	25.987	10.496
the-blue-alliance-android	252	24,094	15.949	15.949	7.099
open-keychain	217	31,038	9.409	106.799	65.869
Ushahidi_Android	100	33,574	54.665	54.665	29.888
cgeo	457	36,963	15.500	93.372	62.235
cgeo	887	42,814	5.729	43.697	34.343
TextSecure	1397	46,469	229.263	229.263	211.488
cgeo	2537	54,765	24.537	24.537	0
WordPress-Android	688	62,344	106.533	106.533	66.409
WordPress-Android	780	62,455	0.001	0.001	0
WordPress-Android	1320	62,895	18.209	74.008	36.374
WordPress-Android	1484	65,307	9.133	9.133	0
WordPress-Android	1122	65,539	27.392	27.392	0
gnucash-android	221	68,158	7.146	7.146	0
cgeo	3991	68,202	18.411	155.640	122.389
WordPress-Android	1928	71,485	14.122	35.444	12.891
calabash-android	149	93,146	161.855	161.855	143.842
Total	-	963,332	899.756	1492.577	1022.140

15双核处理器，8GB内存，Win7



RQ2 – 有用性

- 定性分析
 - 源代码搜索 [GenProg/RSRepair]
 - 模板/转换模式分析 [PAR/SPR]

Issue	Grep Command	Result
TuCanMobile #27	grep "isShowing" -R .	N
OpenIAB #62	grep "super.onDestroy" -R .	N
Onosendai #100	grep "context.getApplicationContext" -R .	N
open-keychain #217	grep "dismissAllowing" -R .	N
cgeo #887	grep "image/jpeg" -R .	N
cgeo #887	grep "image/*" -R .	N
LNReader-Android #62	grep "super.onDestroy" -R .	N
Wordpress-Android #1320	grep "commitAllowingStateLoss" -R .	N
cgeo #3991	grep "isFinishing" -R .	N
cgeo #3991	grep "\btry\b" -R .	Y
cgeo #3991	grep "\bcatch\b" -R .	Y



修复示例

```
24     @Override
25     protected void onDestroy() {
+       super.onDestroy();
26       OpenIAB.instance().unbindService();
        //If there is something wrong with coordinates
27     }

+       try {
562         finish();
+       }
+       catch ( Exception e) {
+         e.printStackTrace();
+       }
563     return;
```



摘要

- 使用因特网资源（问答网站）修复崩溃缺陷
- 使用崩溃踪迹中的文本可以帮助提取web网页
- 分析问答网页中的代码能有效帮助缺陷修复
- 在复发的崩溃缺陷中，精度80%，召回率 30%



C语言内存泄漏的自动修复

高庆，熊英飞，米亚晴，张路，
杨纬坤，周钊平，谢冰，梅宏

北京大学软件工程研究所
发表于ICSE'15



内存管理

- 软件工程经典问题，数千篇论文
- 垃圾回收
 - 广泛用于Java, Go等大量新语言
 - 通过动态扫描内存发现需要回收的内存





垃圾回收 vs 安全攸关软件

- 大量系统资源无法通过垃圾回收管理
 - 文件句柄、线程锁等
- 特定类型的软件无法使用垃圾回收管理
 - 实时嵌入式系统，运行资源有限
 - 大数据处理系统，垃圾收集耗时过长
 - 处理数据量达到10G时，垃圾收集运行时间占程序运行总时间一半以上





内存泄露的例子

```
1 #include <stdlib.h>
2 #include <stdio.h>
3
4 void f(int *p, int **q){
5     *q = p;
6 }
7 void g(int *p){
8     free(p);
9 }
10 int h(int size, int num, int sum){
11     int *p = (int*)malloc(sizeof(int)*size);
12     int **q = (int**)malloc(sizeof(int*));
13     if (size == 0)
14         q(p);
15     else
16         for (int i = 0; i < size; ++i)
17             if (p[i] != num){
18                 f(p, q);
19                 sum += (*q)[i];
20             }
21         else
22             return i;
23     printf("%d", sum);
24     return sum;
25 }
```

内存分配 ←

内存释放 ←

内存使用 ←

泄露 ←

泄露 ←



内存泄露的例子

```
1 #include <stdlib.h>
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4 void f(int *p, int **q){
5     *q = p;
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7 void g(int *p){
8     free(p);
9 }
10 int h(int size, int num, int sum){
11     int *p = (int*)malloc(sizeof(int)*size);
12     int **q = (int**)malloc(sizeof(int*));
13     if (size == 0)
14         g(p);
15     else
16         for (int i = 0; i < size; ++i)
17             if (p[i] != num){
18                 f(p, q);
19                 sum += (*q)[i];
20             }
21     else
22         return i;
23     printf("%d", sum);
24     return sum;
25 }
```

free(q); ←

free(p);
free(q); ←

free(p); ←
free(q); ←



修复内存泄露仍是难题

- 需要考虑多个条件
 - 内存释放前必须已分配
 - 内存释放时必须要有能从栈上访问的路径
 - 在任意路径上，内存不能被释放两次
 - 在任意路径上，内存使用前不能被释放
- 漏掉任何一条都将导致致命错误
- 实践中，常常出现发现内存泄露但不敢修改的情况

研究成果：自动内存修复技术



- 通过对C程序代码的分析，自动查找内存泄露并修复
- 保证修复的正确性
 - 对于任意插入的free语句和任意执行路径
 - 释放前分配：在执行到free之前所指的内存已经分配
 - 无双重释放：在该路径上没有任何其他free语句释放同一块内存
 - 无释放后使用：在该free之后所释放内存不能再被使用
- 能在较短时间内完成对大型程序的分析工作
 - 10万行量级的程序约2分钟完成分析
- 能自动修复一定数量的内存泄露
 - 自动修复了SPEC2000上约30%的内存泄露



技术路线和创新

- 反复使用数据流分析



- 处理各种复杂情况

- 循环、全局变量、多重分配、空指针判断等问题

- 在一定程度上，用数据流分析的效率达到了较高精度分析的效果



软件配置的交互式修复

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Variability Models & Configurators



Configuration

The image shows three overlapping screenshots of configuration tools. On the left is a terminal window for Linux Kconfig showing a menu with options like 'Generic Driver Options' and 'First Android Driver'. In the center is the eCos Configuration Tool showing a table of configuration parameters such as 'Object Pool Configuration', 'Buffer Size (KB)', and 'Pre-Allocation Size'. On the right is the pure::variants GUI showing a hierarchical tree of features for a 'Weather Station' project, including 'Sensors', 'Output', and 'PC Data transfer'.

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

Variability Models



eCos Configurator - Errors

The screenshot shows the eCos Configuration Tool interface. The main window is titled "unnamed3* - eCos Configuration Tool". The menu bar includes File, Edit, View, Build, Tools, and Help. The toolbar contains icons for file operations and help. The configuration tree on the left shows a hierarchy: Configuration > Object Pool (v3_0) > Preload (checked) > Preload Size (10). The "Preload Size" item is selected, and its properties are displayed in the right pane. The error message "Requires PreloadSize <= PoolSize" is shown in the top section of the right pane.

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 Configuration Tool interface. The left pane displays a tree view of configuration options. The right pane shows a table of properties and values for the selected item.

Item	Property
Object Pool	PreloadSize
	Requires PreloadSize <= PoolSize

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

Configuration options in the left pane:

- Object Pool (v3_0)
 - Buffer Size (KB): 4
 - Object Size (Byte): 512
 - Pool Size: 8
 - Preload (checked)
 - Preload Size: 10
 - Allocation_Time
 - Startup (disabled, highlighted with blue box)
 - First Access (checked)
 - Idle (unchecked)

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

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
<input checked="" type="checkbox"/> Preload	
Preload Size	10
Allocation_Time	
<input type="checkbox"/> Startup	
<input checked="" type="checkbox"/> First Access	
<input type="checkbox"/> Idle	

Resolve conflicts

Continue Cancel

Item	Property
PreloadSize	Requires PreloadSize <= PoolSize

Proposed Solutions:

None All

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

Essentially, fixes work for both resolving errors and activating options



Fix Incompleteness

The image shows two overlapping windows from the eCos Configuration Tool. The background window is the configuration tool, and the foreground window is the 'Resolve conflicts' dialog.

Configuration Tool:

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"/>

Resolve Conflicts Dialog:

Item: PreloadSize
Property: Requires PreloadSize <= PoolSize

Proposed Solutions:

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

Annotations:

- An orange box with the text "Increase to any value ≥ 10 " points to the "PreloadSize" property in the dialog.
- An orange box with the text "Further decrease to any value ≤ 8 " points to the "8" value in the "Proposed Solutions" table.
- A red circle highlights the "8" value in the "Proposed Solutions" table.
- A red circle highlights the "8" value in the "Pool Size" row of the configuration tool.
- An orange box with the text "Disable" points to the "Preload" checkbox in the configuration tool.

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



How to complete fixes

The screenshot shows the eCos Configuration Tool interface. The left pane displays a tree view of configuration options. The right pane shows a list of configuration parameters and their values. A list of fixes is overlaid on the right pane.

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"/>

Configuration Parameters:

- 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 interface. The left pane shows a tree view of configuration items. The right pane shows a table of properties for the selected 'Preload Size' item. A callout box highlights three range fixes:

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

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

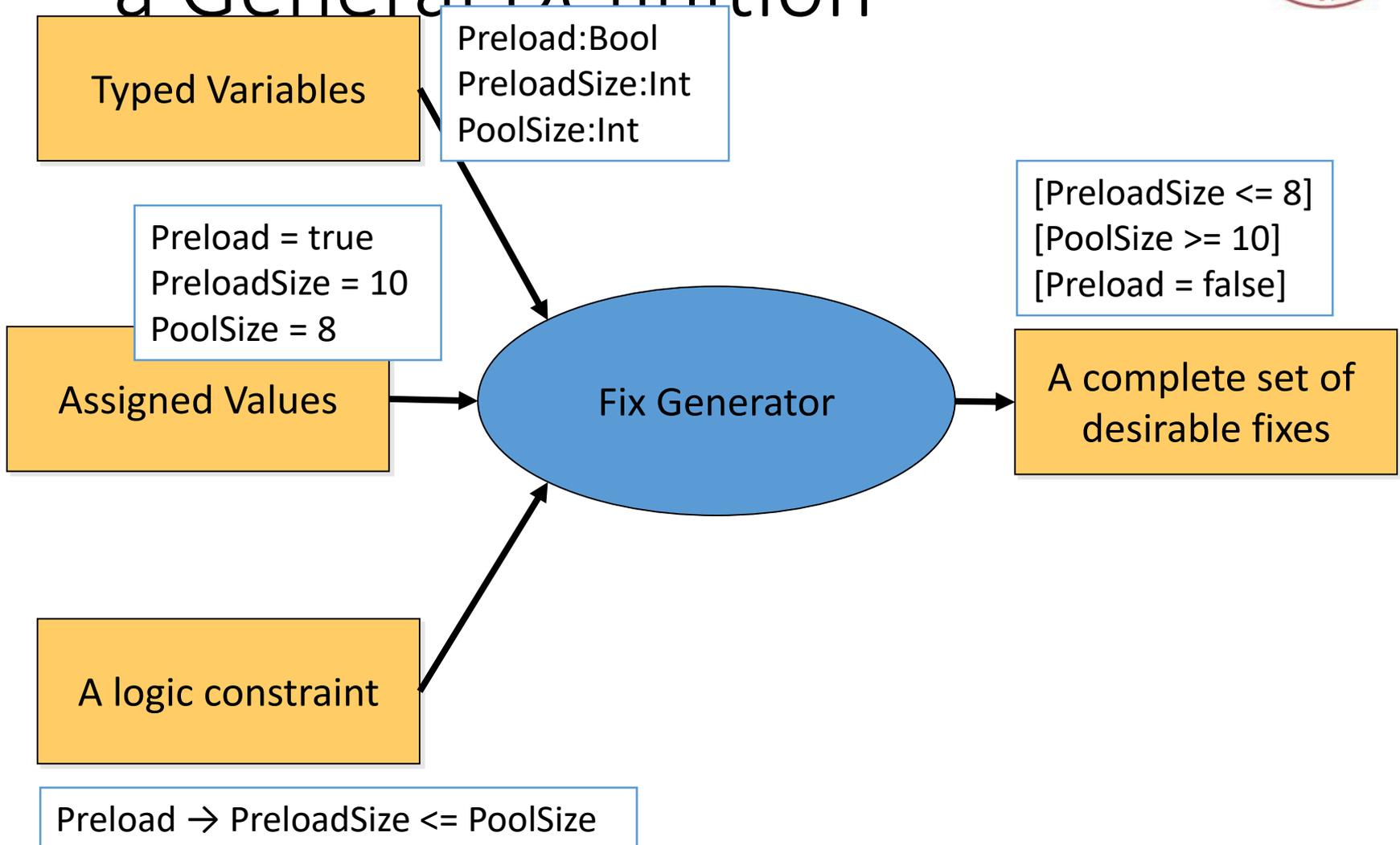


Our Contributions

- 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 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 \rightarrow PreloadSize \leq 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 \rightarrow PreloadSize ≤ 8
 - ② simplify the constraint and convert to CNF
 - [PreloadSize ≤ 8]



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



谢谢！