LAD: A Layout Anomaly Detector for Android Applications

Cheng-Zen Yang, Chih-Ju Lai, Peng Lu, and Zhi-Jun You

Department of Computer Science and Engineering

Yuan Ze University

Chungli, Taiwan, R. O. C.

{czyang,cjl16,pl16,zjy19}@syslab.cse.yzu.edu.tw

Abstract— In recent years, Android has become one of the most popular mobile operating systems. Software testing of Android applications becomes a very important issue. In the past research, many studies focus on functional testing. Recently, some studies start to discuss the layout anomaly issue. However, these schemes investigate few types of layout anomalies. Moreover, there may exist underlying platform constraints. In this paper, a detection tool LAD (Layout Anomaly Detector) is proposed. LAD considers the anomaly types studied in the previous work with a newly proposed anomaly type for scale maladaptation of components and text. LAD also supports testing scripts. We have conducted empirical experiments with four real apps. The experimental results show that LAD can effectively detect the layout anomalies of these apps.

Keywords—Android; layout anomaly; GUI layout testing; automatic testing

I. INTRODUCTION

As shown in the statistics of AppBrain, the number of Android apps has exceeded 2.59 million on Google Play in March 2019 [1]. In the past, automatic Android software testing has received many attentions, such as [2-5]. However, most of the previous studies focus on functional testing. To our best knowledge, the number of research studies on detecting layout anomalies for Android apps is comparatively few [6-9]. Because Android devices have the severe fragmentation problem, layout anomalies become an important issue for user experience.

The layout anomaly problem occurs in an app if its layout design does not consider the diversity of different screen specifications. This problem can be very annoying for users and app developers. For example, the layout anomalies such as UI component overlap or cropped text may hamper the user operations. As reported in [8], some UI components may even disappear when the app is executed in a smaller screen size.

To tackle layout anomalies, app developers need to take a lot of time to inspect the layouts for many screen specifications. As illustrated in [8, 9], if there are m layouts in an app and n screen specifications, the time complexity of the inspection work is $O(m \times n)$. This workload is harmless if n is very small. However, a survey of OpenSignal shows that over 150 different screen sizes have existed for Android devices in 2014 [10]. If there are 100 different screen specifications to be inspected and the inspection time is 5 minutes per layout, the total inspection time will be 83 hours for an app of 10 layouts.

In recent years, studies have been conducted to deal with the problem of layout anomaly detection. Several tools like Galen Framework [6] and ITArray Automotion Framework [7] are developed to perform visual testing for Android apps. Their users need either to write scripts to specify the geometry relationships or to import the customized Java code into the app under testing (AUT). In 2017, Shih *et al.* proposed an automatic detection tool called UI-Explorer to detect two types of layout anomalies [8]. In UI-explorer, all layouts are traversed and inspected automatically. However, UI-explorer provides only click events to traverse the layouts. It lacks an approach to handle user inputs. Hasellknippe and Li also proposed a tool called the Layout Bug Hunter (LBH) to detect three different types of layout anomalies [9]. LBH does not need any user specification. However, LBH relies on the underlying Fuse platform [11] to implement the GUI analytical work.

In this paper, we propose a layout anomaly detection tool called LAD (Layout Anomaly Detector) to perform visual testing on Android app layouts. LAD is designed to detect six types of layout anomalies: *components missing*, *cropped text*, *component overlap*, *component overflow*, *component misalignment*, and *component/text scale maladaptation*. To automate the detection process, a procedural script language is devised to specify the navigation procedure and the detection operations. LAD also supports two inspection modes: the *standalone* mode and the *comparative* mode. In the comparative mode, users specify a designated resolution to get *gold standard layouts* (GSLs) as the inspection templates. LAD automatically inspects all *layouts under test* (LUTs) in the testing resolutions against the GSLs. In the standalone mode, LAD works only for one testing resolution. To operate in a contiguous integration (CI) testing process, LAD is designed as a native Java tool in a modular design.

The rest of this paper is organized as follows. Section 2 briefly reviews the related research work on the layout anomaly detection problem. Section 3 describes the layout anomalies detected in LAD and the LAD design. Section 4 presents the empirical study on LAD with four Android apps. Finally, Section 5 concludes this paper.

II. RELATED WORK

The layout anomaly detection problem is an important issue for traditional window-based interface design and Web application design [12-14]. For automatically detecting layout

anomalies, the detection approaches can be mainly classified into two categories: the image comparing approach [15, 16] and the layout analysis approach [6-9].

The image comparing approach inspects the layout anomalies by making comparisons between two captured screenshots to find their pixel differences. Since there is no layout structure information in the contrasting process, this approach may suffer from the challenge to decide whether two images presented in different screen sizes/resolutions are identical [9].

For the layout analysis approach, the layout information is used to detect the anomalies. In Galen Framework [6], users can program the test cases using Galen Specs Language to describe the relationships between two objects. However, Galen is mainly designed for Web apps. In ITArray Automation Framework [7], a library is supported to perform visual testing on web and mobile pages. Users can describe the visual relationships using the library calls. As pointed in [9], however, these tools require users to provide detailed information about the placement of GUI objects and the validation parameters. If the GUI layouts are changed frequently, this scripting-in-detail approach may incur high maintenance costs.

In 2017, Shih *et al.* proposed a tool called UI-Explorer to automate the detection of layout anomalies [8]. UI-Explorer uses a GUI ripping engine to extract the layout information of all GUI components and automatically traverse all layouts under two different screen specifications. With UI-Explorer, users do not need to provide detailed visual information for testing. However, UI-Explorer considers only two types of layout anomalies: *components missing* and *cropped text*. Moreover, it provides only click events to traverse the layouts.

Hasellknippe and Li proposed a tool called the Layout Bug Hunter (LBH) for detecting three GUI layout anomalies: *component overlap*, *component overflow*, and *component misalignment* [9]. LBH employs a set of specified rules to detect layout anomalies. Therefore, LBH does not require any script for its visual testing. However, LBH does not consider the comparative approach. As discussed in [9], an intentional overlap design may be identified as an anomaly. Moreover, the current LBH design relies on the underlying Fuse platform [11].

III. DESIGN OF LAYOUT ANOMALY DETECTION MECHANISMS

This section first presents the layout anomalies considered in LAD. The design of the LAD architecture is described thereafter.

A. Layout Anomalies

In addition to the layout anomaly types discussed in the previous studies [8, 9], *components missing*, *cropped text*, *component overlap*, *component overflow*, and *component misalignment*, LAD considers one more type: *component/text scale maladaptation*. LAD supports two inspection modes for layout anomaly detection: the *standalone* mode and the *comparative* mode. In the *standalone* mode, LAD uses the pre-defined heuristic rules to decide the detection results. In the *comparative* mode, the layouts in a user-designated resolution are used as the inspection templates, which are the *gold standard*

layouts (GSLs). The *layouts under test* (LUTs) in different screen sizes/resolutions will be investigated against the GSLs.

1) Component Missing

A component missing anomaly happens when some GUI component disappears in a different LUT screen size/resolution. Generally, this anomaly occurs when the screen size/resolution becomes smaller. As shown in Figure 1, the gender symbol at the bottom of the app in the 768×1280 GSL disappears in the 480×800 LUT.

Figure 1: Component missing anomaly

To detect component missing anomalies, LAD first retrieves the XML dumps of GSLs and LUTs. From the XML dumps, LAD calculates the total numbers of components of each GSL and the corresponding LUT. If these two numbers are not equal, the LUT is regarded as having a component missing anomaly.

2) Cropped Text

The cropped text anomaly happens when some text string correctly appears in the GSL, but it is cropped in the corresponding LUT. Generally, this anomaly occurs because the GUI components are squeezed in the LUT of a smaller screen resolution. As shown in Figure 2, when the 768×1280 GSL resolution is shrunk to the 480×800 LUT resolution, the text in the red box of Figure 2(b) is cropped. In this case, the app user cannot read the complete text.

Figure 2: Cropped text anomaly.

LAD uses the same approach proposed in [8] to first obtain the coordinates of the text component C_1 in the GSL and invoke OpenCV (a computer vision library) to get a screenshot S_1 of C_1 . LAD then invokes Tesseract (an OCR text recognizer) to perform the OCR work and get the OCR text T_1 . Similarly, LAD gets the OCR text T_2 for the corresponding component C_2 in the LUT. For example, T_1 in the red box of Figure 2(a) is recognized as “Getlowermember-onlypricesinstantlywhenyousignin” and T_2 is recognized as “GetlowermemberonlypricesWMin-”.

Because the OCR results usually have errors, LAD calculates the Levenshtein distance (Ed_1) between T_1 and the original string $C_1.text$. LAD also calculates Ed_2 between T_2 and $C_1.text$. Therefore, if $|Ed_1 - Ed_2| \geq T_{ED}$ where T_{ED} is a predefined threshold, the LUT is regarded as having a cropped text anomaly.

3) Component Overlap

The component overlap anomaly happens when one GUI component covers a part of another GUI component. This may occur when a smaller screen size/resolution is used for LUTs. However, the original design may also contain this anomaly. Therefore, LAD detects it in both inspection modes.

Figure 3 shows an example in which Figure 3(a) is a correctly displayed GSL of a calculator app. In Figure 3(b), the dashed button area overlaps the background text area in the LUT. In this case, the app users cannot get the correct result.

Figure 3: Component overlap anomaly.

To detect component overlap anomalies, LAD retrieves the XML dumps of LUTs and obtains the coordinates of the upper left corner and the lower right corner of each component C_i from the XML dumps. Then LAD calculates the areas of two components to see if these two areas are overlapped.

4) Component Overflow

When an app developer forgets to adjust the component size according to the new LUT resolution, a component overflow anomaly may occur in the LUT if the area of some component exceeds the screen boundary. In the worst case, users may not be able to correctly operate the component.

Figure 4 shows an example. In the 768x1280 GSL of Figure 4(a), both button components are completely displayed. In

Figure 4: Component overflow anomaly.

Figure 4(b), however, the area of BUTTON1 exceeds the boundary of the 480x800 LUT layout.

LAD also analyzes the XML dumps of LUTs to obtain the coordinate (x_{i1}, y_{i1}) of the upper left corner of each component C_i and its coordinate (x_{i2}, y_{i2}) of the lower right corner. LAD also analyzes the component information to get the height H_i and the width W_i . LAD compares these values with the screen height S_h and the screen width S_w , respectively. If one of the following inequalities is satisfied, the LUT is regarded as having a component overflow anomaly.

- Horizontal boundary overflow

$$x_{i1} + W_i > S_w \parallel x_{i2} < W_i \parallel x_{i2} > S_w$$

- Vertical boundary overflow

$$y_{i1} + H_i > S_h \parallel y_{i2} < H_i \parallel y_{i2} > S_h$$

5) Misalignment

When a programmer designs a layout, the components are usually aligned in the layout. There are three kinds of vertical alignment: *Align Top*, *Align Middle*, and *Align Bottom*. Similarly, the horizontal alignment also has three kinds: *Align Left*, *Align Center*, and *Align Right*. When the component position is not properly adjusted with the resolution change, it is possible that a

Figure 5: Component misalignment anomaly.

component misalignment anomaly occurs in the LUT resolution. For example, the 768×1280 GSL in Figure 5(a) illustrates that the left sides of BUTTON3 and BUTTON4 are aligned with the right side of BUTTON1 along with the red line. However, the 480×800 LUT in Figure 5(b) demonstrates that BUTTON1 is not horizontally aligned with BUTTON3 and BUTTON4.

To detect component misalignment anomalies, LAD makes comparisons for each pair of two components C_i and C_j using their coordinates and centers. However, a strict alignment judgement may incur many false alarms for two cases:

- Some very minor misalignments can be allowable because it is very hard for users to find them by eyes.
- Some misalignments are intentionally designed.

Therefore, LAD has two thresholds D_S and D_L to control the misalignment detection. D_S is used to ignore the misalignments that are not easily recognized by users. In the current LAD design, the default value of D_S is 2 pixels. D_L is used to ignore the misalignments that are intentionally designed. In LAD, the default value of D_L is 8 pixels. For example, if the left upper corner of C_i is (x_{i1}, y_{i1}) and the left upper corner of C_j is (x_{j1}, y_{j1}) , the LUT is regarded as having a component misalignment anomaly when the following condition is satisfied.

$$D_S < |x_{i1} - x_{j1}| < D_L$$

6) Component/Text Scale Maladaptation

As the resolution of the screen changes, the sizes of the components and text characters may also change. If the size of a component is excessively reduced, users will have difficulty clicking the component or reading the text. The LUT is regarded as having a component/text scale maladaptation anomaly. LAD tackles this scale maladaptation problem separately for GUI components and text strings.

For GUI components, the size of an interactive component should be at least 44 pt × 44 pt according to the Apple User Interface Design Guide [17]. In [18], however, Zea suggests that the minimum target size of the component should be 5 mm × 5 mm = 30 px × 30 px. In the current LAD design, we use the size suggested by Zea as the threshold to determine the scale maladaptation anomaly for a component. If the size of a component is smaller than this threshold, a scale maladaptation

Figure 6: Component scale maladaptation anomaly in 768×1280 LUT.

Figure 7: Text scale maladaptation anomaly.

anomaly occurs on the component. For example, Figure 6 illustrates that the dashed area is smaller than 5 mm × 5 mm in the 768×1280 LUT.

For the text scale problem, Kahn and Lenk have pointed out that the font sizes of 12 and 14 points allow the user to read comfortably [19]. Tennant also points out that the 16-pixel font size is approximately equal to the 12-point font size which is suitable for reading [20]. Because the height of the 12-point font is approximately 0.42 cm, LAD use this as a default threshold to determine if the scale of a text string is maladapted in the LUT.

Figure 7 illustrates an example in which LAD first gets the coordinates of the dashed box containing a string “Return date” and then invokes OpenCV to get its screenshot. LAD then uses a text edge detection algorithm [21] to obtain the height H_T of the string as shown in Figure 7(b). If $H_T < 0.42$ cm, the LUT is regarded as having a text scale maladaptation anomaly.

B. LAD Architecture

1) Script Language

To automate the visual testing, a script language is devised in LAD for controlling the testing procedure. With the test scripts, LAD can automatically enter text inputs into the

(a) Component marking

(b) Component list

Figure 8: Component marks and the list of their IDs.

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1: #Username
2: LAD.input[@id='editText','User']
3: #Password
4: LAD.input[@id='editText2','1234']
5: LAD.testoverlap
6: button.click
7: LAD.testall

```

Figure 9: An example script.

components and navigate to different layouts. In order to let the script writer know the component IDs of each layout, LAD has a companion tool LADMark to extract the component IDs and mark each component on the layout screenshot as shown in Figure 8(a). Figure 8(b) is the component list.

Figure 9 shows a script example based on the list in Figure 8(b). A starting “#” is used to denote a comment. On the second line, “LAD.input[@id='editText','User']” is used to enter the text input “User” for the username. On line 4, “LAD.input[@id='editText2','1234']” is used to input the password “1234”. On line 5, LAD.testoverlap instructs LAD to perform anomaly detection for component overlap. On line 6, button.click tells LAD to click the LOGIN button such that the app moves to the next layout. Finally, LAD.testall instructs LAD to perform anomaly detection for all kinds of anomalies.

2) Architecture Design

Figure 10 shows the architecture of the LAD. The system reads the AUT, the LUT screen resolution, the GSL screen resolution, and the testing scripts. Then, LAD analyzes the testing scripts and automatically navigates the GSLs and LUTs for testing.

Finally, LAD collects the testing results and generates the detection report. To help the developer find the corresponding places of the detected anomalies, the report contains the

Figure 10: Detection system architecture.

Figure 11: A detection report example.

screenshots, the detection results, and the XML information of the problematic components. Figure 11 illustrates a report example.

IV. EXPERIMENTS

To evaluate the effectiveness of the proposed anomaly detection mechanism, we have conducted experiments with four Android apps. This section describes the experimental results.

A. Experimental Environment

We have implemented a prototype for experiments. The LAD prototype was executed on a PC running with 16 GB RAM and an Intel i5-6500 3.20 GHz CPU. The operating system was Ubuntu 16.04 64bit. The Android emulator was the built-in emulator of Android Studio 3.1 emulating Google 7.0.0 API 24. The resolutions of GSL and LUT were 768×1280 and 480×800, respectively. Four investigated apps are as follows:

- **MunchLife** 1.4.4 (ML): This app is used to track the character level for a card game Munchkin.
- **Last Minute Flights Booking** 2.0 (LMFB): This app allows users to compare flight and hotel information provided by airlines and travel agencies. Users can use it to find the most suitable flights and hotels.
- **Priceline** 4.34.170 (PL): This app allows users to quickly plan their travel itineraries, including booking cheap flights, hotels and rental cars.
- **MyAir365** 1.06 (MA): This app allow users to easily order low-cost airlines.

The main reason for choosing these four apps is that they all have layout anomalies. Therefore, they can be used to demonstrate the detection performance. In order to clearly present the detection results, this paper shows the experimental results using only the first page of each app.

B. Experimental Results

As shown in Table 1, the numbers are the anomalies detected in the experiments. For anomalies of *components missing*, *cropped text*, *component overlap*, *component overflow*, and *component misalignment*, the results are obtained in the *comparative* mode. For scale maladaptation anomalies, the results are measured in the *standalone* mode with the 768×1280

TABLE I. DETECTION RESULTS OF LAD.

	ML	LMFB	PL	MA
Comp. missing	1	0	0	0
Cropped text	0	3	4	0
Overlap	2	10	0	7
Overflow	0	0	0	0
Misalignment	0	6	0	11
Comp. scale maladapt.	0	5	8	8
Text scale maladapt.	5	10	8	3

resolution. The manual inspections show that these detection results can effectively discover many anomalies which may be ignored by inspectors.

In the experiments, some false alarms were found in the standalone mode because the default heuristic thresholds are not appropriate for some apps and scree specifications. However, these false alarms can be eliminated in the comparative mode because the GSLs can filter out their detections in the LUTs.

V. CONCLUSION

Since Android has the severe fragmentation problem, visual testing has received considerable attentions in recent research. Traditionally, developers need to spend much time in manually checking layouts with different screen resolutions. This manual inspection process is time-consuming and error-prone.

In this paper, we present the design of an anomaly detection tool LAD which can be used to detect six types of layout anomalies. To automatically detect these anomalies in different layouts, a procedural script language is devised to specify the app navigation procedure and the detection operations. To operate in a contiguous integration (CI) testing environment, LAD is designed as a native Java tool in a modular design. Moreover, LAD supports two inspection modes: the *standalone* mode and the *comparative* mode. The *comparative* mode facilitates the avoidance of false alarms in the detection results.

In our future work, we plan to conduct comprehensive investigations with more apps to study the effectiveness of LAD. Human inspectors will also involve the experiments to make performance comparisons by measuring more metrics, such as accuracy, precision, and recall. Moreover, the functionality of LAD will be enhanced. The current design does not have a plug-in interface. Therefore, it is inflexible for users who want to add a new module for a new anomaly. The algorithms for anomaly detection will be also improved further and the practical applicability of the detection reports will be enhanced to help developers quickly detect the layout anomalies and improve the quality of Android apps.

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