How to Test Location-based Mobile Apps

Jing Cheng
School of Computer Science
Northwest Polytechnical University,
Xi’an, China
chengjing@nwpu.edu.cn

Jerry Gao
Department of Computer Engineering
San Jose State University,
San Jose, USA
jerry.gao@sjsu.edu

Yi-an Zhu
School of Computer Science
Northwest Polytechnical University,
Xi’an, China
zhuya@nwpu.edu.cn

Tao Wang
School of Software Engineering
Northwest Polytechnical University
Xi’an, China
850767660@qq.com

Tao Zhang
School of Software Engineering
Northwest Polytechnical University
Xi’an, China
tao_zhang@nwpu.edu.cn

ABSTRACT — Location-based services are growing in popularity due to the ubiquity of smartphone users. The availability and validity of location-based services are often affected by mobile user location contexts, which make mobile location-based services testing becomes one urgent and challenging issue. In this paper, we analyze location related features for location-based mobile apps. Then some test strategies are proposed to test those location related features and characteristics. Moreover, a case study is reported to describe our test approaches and test steps in details.

CCS Concepts
• Software and its engineering – Software testing and debugging
• Human-centered computing – Mobile computing

Keywords — Location-based services; mobile testing; mobile apps; test approach;

I. INTRODUCTION

Location-based mobile apps provide many interesting and convenient location-based services (LBS) and functions, and bring many surprising and exciting user experiences[1]. For example, mobile tourism app “Tripadvisor (tripadvisor.com)” helps to find nearby hotels and restaurants; mobile social app “Momo (immomo.com)” helps to find nearby friends; and mobile game “Life is Crime (redrobot.com)” make mobile players to fight with other players in the same location contexts.

Mobile location-based services have been identified as the one of most important features of mobile app services [2], and have become one hot research topic in mobile computing domains. In the recent years, there have been a number of published research papers addressing LBS. However, most papers primarily focus on infrastructure [3,4], positioning techniques [5], location privacy preserving [6,7], and other areas.

Till now, there are a few publications discussing mobile LBS testing. There is a lack of systematic and effective test approaches for test engineers to address mobile LBS testing. For mobile LBS testing, test engineers often are confused by following questions:

1) How to select and test location contexts form wide areas?
2) How to test location related information and services?
3) How to test moving objects with moving paths?
4) How to test location related interactive behaviors between multiple mobile users and objects?

ABSTRACT — Location-based services are growing in popularity due to the ubiquity of smartphone users. The availability and validity of location-based services are often affected by mobile user location contexts, which make mobile location-based services testing becomes one urgent and challenging issue. In this paper, we analyze location related features for location-based mobile apps. Then some test strategies are proposed to test those location related features and characteristics. Moreover, a case study is reported to describe our test approaches and test steps in details.

Goal of this work is to provide an answer to those urgent questions. We analyze features of location-bases mobile apps firstly. Then some key test strategies and test approaches are proposed for solving above questions, and a case study is also presented to describe test approaches in details. Finally, concluding remarks and future research directions are given.

II. LOCATION-RELATED FEATURES

Location-based mobile apps have some special location-related features, such as map, location contexts, location objects, location-based information, location-based services and behaviors, and moving patterns and paths.

Map is the basic component of location-based mobile apps, which displays location contexts, and positions of mobile users and other location objects. Most of mobile LBS use third-party map service, such as Google Maps, Apple Maps, Baidu Maps, etc.

Location contexts represent different physical positions, mobile environments, and location-based user contexts, which affect information, behaviors and services provided by mobile Apps.

Location objects are objects with geographical positions, which may represent hotels, restaurants, mobile users, cars, or sensors in mobile apps. Location objects may be static or moving, provide static or dynamic information, and interact with nearby other location objects.

Location-based information is recommended and provided based on the geographical position of mobile users, such as position information, nearby business information, and local advertisements and news.

Location-based services include basic location services and domain related location services. There are three mainly basic location services, including map service, position service, and navigation service. There are different domain related location services, for example, location-based advertisement service, search nearby friend service, report nearby jam service, etc.

Mobile users and moving objects have various moving patterns and paths, which will change geographical positions of mobile users and location objects, and also change location relations between mobile users and location objects. Then moving patterns and paths bring many uncertainties for location-related mobile apps.

In table 1, we analyze location related features for four popular location-based mobile apps: TripAdvisor, Waze, Momo, and Life is Crime.
<table>
<thead>
<tr>
<th>Mobile Apps</th>
<th>TripAdvisor</th>
<th>Waze</th>
<th>Momo</th>
<th>Life is Crime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Site</td>
<td>tripadvisor.com</td>
<td>waze.com</td>
<td>immomo.com</td>
<td>redrobot.com</td>
</tr>
<tr>
<td>Domain</td>
<td>Business</td>
<td>Traffic</td>
<td>Social network</td>
<td>Fight Game</td>
</tr>
<tr>
<td>MAP</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Location Area</td>
<td>About 39 Countries</td>
<td>About 190 countries</td>
<td>China</td>
<td>About 120 countries</td>
</tr>
<tr>
<td>Static Objects</td>
<td>Restaurants, Hotels, Tourist spots, Malls, and Event centers</td>
<td>Traffic jams, Accidents, Cameras, Police, Dangers, Gas stations,</td>
<td>No</td>
<td>Houses, Shops, Streets,</td>
</tr>
<tr>
<td>Moving Objects</td>
<td>Mobile users</td>
<td>Auto, friends</td>
<td>Nearby friends</td>
<td>Mobile users, Polices</td>
</tr>
<tr>
<td>Location-based Information</td>
<td>Position information, Business information</td>
<td>Information about traffic jams, accidents, cameras, police, dangers, and gas stations,</td>
<td>Information about nearby friends</td>
<td>No</td>
</tr>
<tr>
<td>Basic location Service</td>
<td>Third party map, such as Google Map</td>
<td>Own map service</td>
<td>No</td>
<td>Own map service</td>
</tr>
<tr>
<td>Position service</td>
<td>GPS</td>
<td>GPS</td>
<td>GPS</td>
<td>GPS</td>
</tr>
<tr>
<td>Navigation Service</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Domain-related Location Services</td>
<td>Search nearby object service</td>
<td>Report nearby event services, Display nearby friend service</td>
<td>Search nearby user service</td>
<td>Fight with nearby players</td>
</tr>
<tr>
<td>Mobile patterns</td>
<td>On feet, By car</td>
<td>By car</td>
<td>On feet, By car</td>
<td>On feet, By car</td>
</tr>
</tbody>
</table>

III. TEST STRATEGIES AND APPROACHES

There are four key steps for testing location-based mobile apps: 1) select mobile test devices; 2) select and test location contexts; 3) test location objects, location-based services and behaviors; 4) test moving patterns and paths. In this section, we use Waze as an example to explain how to test location-based mobile apps in details.

A. Select and prioritize mobile test devices

There are thousands of mobile devices with diverse appearances, architectures, and platforms. It is impossible to test location-based mobile apps on all thousands of devices with restricted test resources. There are two main strategies for selecting mobile test devices as below:

a) Select a set of mobile test devices to cover all compatibility features;
b) Select a set of popular mobile devices;

Those two strategies should be combined to select mobile test devices. Higher coverage helps to discover more faults, and testing popular devices helps to reduce fault damages on mobile users. In table 2, we list 10 mobile devices selected from Amaze to test “Waze”, those test devices contain diverse compatibility features, and also have higher market shares.

B. Select and test location contexts

Location-based mobile apps are used in wide areas, and then only limited location contexts are selected to test because of restricted test resources. We select and test location contexts according to below strategies:

a) Select and prioritize the location contexts containing more location objects;
b) Select and prioritize the location contexts appearing more mobile users;
c) Select a set of typical user location contexts;
d) Select a set of location contexts with diversity using environments;

The location contexts including more location objects and mobile users are selected and tested to achieve higher test coverage and find more bugs. Typical user location contexts represent mobile apps frequently used in those location contexts. Diversity using environments mean different position environments (such as indoor position, GPS position, and network position) and network environments (such as 2G, 3G, 4G, and WiFi).

Normally, we randomly generate a large number of test location contexts considering location distributions of mobile users and location objects firstly. Then we select and prioritize a small set of location contexts using above strategies according to test resources and costs.

For example, we generate 200 initial location contexts for Waze. And then we select a set of 5 location contexts as test location contexts, as shown in table 3. The number of objects and mobile users are changing, so we calculate the average number of objects and mobile users for every location context. Waze is used...
for providing navigation services, and then user contexts are designed to test Waze in different road contexts, such as: street, high way, country road, beach path, etc.

**TABLE II. SELECTED MOBILE TEST DEVICES FOR WAZE**

<table>
<thead>
<tr>
<th>Device Models</th>
<th>Manufacturers</th>
<th>Mobile platforms</th>
<th>Screen sizes (inches)</th>
<th>Screen resolutions (pixels)</th>
<th>RAM (GB)</th>
<th>Wireless network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple IPhone 5s</td>
<td>Apple</td>
<td>IOS 7.0</td>
<td>4.0</td>
<td>1136*640</td>
<td>1</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>Apple IPhone 6s</td>
<td>Apple</td>
<td>IOS 9</td>
<td>4.7</td>
<td>1334*750</td>
<td>2</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>Apple IPhone 6s plus</td>
<td>Apple</td>
<td>IOS 9</td>
<td>5.5</td>
<td>1920*1080</td>
<td>2</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>Moto x Pure Edition</td>
<td>Motorola</td>
<td>Android OS 5.1</td>
<td>5.7</td>
<td>2560*1440</td>
<td>3</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>OnePlus Two</td>
<td>Micromax</td>
<td>Android OS 5.1</td>
<td>5.5</td>
<td>1920*1080</td>
<td>4</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>Samsung GALAXY S6</td>
<td>Samsung</td>
<td>Android OS 5.0</td>
<td>5.1</td>
<td>2560*1440</td>
<td>3</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>One Touch Idol 3</td>
<td>ALCATEL</td>
<td>Android OS 5.0</td>
<td>4.7</td>
<td>1280*720</td>
<td>1</td>
<td>2G,3G,WI,FI</td>
</tr>
<tr>
<td>Moto G</td>
<td>Motorola</td>
<td>Android OS 4.3</td>
<td>4.5</td>
<td>1280*720</td>
<td>1</td>
<td>2G,3G,WI,FI</td>
</tr>
<tr>
<td>Samsung GALAXY Note 5</td>
<td>Samsung</td>
<td>Android OS 5.1</td>
<td>5.7</td>
<td>2560*1440</td>
<td>4</td>
<td>4G,3G,WI,FI</td>
</tr>
<tr>
<td>Grand X Max+</td>
<td>ZTE</td>
<td>Android OS 4.4</td>
<td>6</td>
<td>1280*720</td>
<td>2</td>
<td>2G,3G,WI,FI</td>
</tr>
</tbody>
</table>

**TABLE III. SELECTED LOCATION CONTEXTS FOR WAZE**

<table>
<thead>
<tr>
<th>Location contexts</th>
<th>Location positions</th>
<th>Average number of location objects</th>
<th>Average number of mobile users</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>40.7142, 70.74, 05970</td>
<td>5845</td>
<td>20156</td>
<td>Grea t city</td>
</tr>
<tr>
<td>San Francisco</td>
<td>9.99299, 84.129340</td>
<td>1825</td>
<td>4099</td>
<td>Big city</td>
</tr>
<tr>
<td>San Jose</td>
<td>9.93333, 84.083330</td>
<td>1547</td>
<td>3784</td>
<td>Sma ll city</td>
</tr>
<tr>
<td>Burnt Corn</td>
<td>31.5534, 87.160260</td>
<td>48</td>
<td>154</td>
<td>Tow n</td>
</tr>
<tr>
<td>San Diego</td>
<td>32.7153, 117.157260</td>
<td>746</td>
<td>3529</td>
<td>Beac h</td>
</tr>
</tbody>
</table>

C. Test location objects and location-based services

In mobile apps, there are different kinds of location objects, which one has thousands, even millions of instances. Every location object provides different information, and has some special behaviors. Then we should test every location object, and its information and behaviors.

For Waze, there are some type of location objects, such as Traffic jams, Accidents, Cameras, Police, Dangers, and Gas stations. We design a set of test cases to check if the positions and information of location objects are right.

There are three mainly basic location services: map service, position service, and navigation service. Position service is provided by mobile platform. Most of location-based apps integrate and use the third party maps and navigation services, which have been tested sufficiently.

However Waze provides map service and navigation service, then some test cases are designed to test Waze map service, such as: zoom in, zoom out, moving. Navigation service is more difficult to test for considering many complex factors, such as traffic jams, dangers, road situations, etc.

Every location-based mobile app also has some special domain-related location services, which should be paid more attentions on testing. Waze provides some domain related location services, such as: report nearby police, report nearby jam, report nearby danger, display nearby friend, etc. We design test cases for every kind of domain-related location services, and those test cases are tested in various location contexts.

D. Test moving patterns and paths

When a mobile user is moving, his location context is continually changing, the wireless network is unstable, and his position is continuously changed. That brings many uncertainties for location-based mobile apps. There are three key factors for design test cases to test moving patterns of mobile users and moving objects.

1) Moving paths

Moving path for mobile user represents continually changing location contexts, wireless network environments, and position environments. There are some typical kinds of moving paths, such
as highway, street, alley, hill pathway, seaside pathway, etc. There are three basic strategies to test moving paths: 1) selecting all kind of moving paths; 2) selecting and prioritizing moving paths with more mobile users; 3) selecting moving paths with complicated network and position environments. For Waze, we select 10 typical moving paths, as shown in Table 4.

### TABLE IV. SELECTED MOVING PATHS FOR TESTING WAZE

<table>
<thead>
<tr>
<th>Location context</th>
<th>Path name</th>
<th>Start position</th>
<th>End position</th>
<th>Path type</th>
<th>Path length (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New York</td>
<td>Murray Street</td>
<td>40.715029, -74.013122</td>
<td>40.712927, -74.007248</td>
<td>Street</td>
<td>692</td>
</tr>
<tr>
<td>New York</td>
<td>Brooklyn-Battery</td>
<td>40.705172, -74.015101</td>
<td>40.707148, -74.014924</td>
<td>Tunnel</td>
<td>220</td>
</tr>
<tr>
<td>San Francisco</td>
<td>Central Freeway</td>
<td>37.771685, -122.423245</td>
<td>37.769222, -122.410810</td>
<td>Freeway</td>
<td>1407</td>
</tr>
<tr>
<td>San Francisco</td>
<td>Duboce Avenue</td>
<td>37.769319, -122.429280</td>
<td>37.769185, -122.433185</td>
<td>Avenue</td>
<td>433</td>
</tr>
<tr>
<td>San Jose</td>
<td>Guadalupe Parkway</td>
<td>37.370067, -121.926628</td>
<td>37.260626, -121.859090</td>
<td>Parkway</td>
<td>15604</td>
</tr>
<tr>
<td>San Jose</td>
<td>Blossom Hill Road</td>
<td>37.257180, -121.794240</td>
<td>37.235722, -121.977623</td>
<td>Hill Road</td>
<td>20494</td>
</tr>
<tr>
<td>Burnt Corn</td>
<td>Sand Bottom Road</td>
<td>31.553490, -87.160260</td>
<td>31.582154, -87.213281</td>
<td>Country Road</td>
<td>6690</td>
</tr>
<tr>
<td>Burnt Corn</td>
<td>Conecuh Country</td>
<td>31.550050, -87.159551</td>
<td>31.334568, -87.150989</td>
<td>State Road</td>
<td>23937</td>
</tr>
<tr>
<td>San Diego</td>
<td>Pacific Highway</td>
<td>32.711206, -117.171088</td>
<td>32.766942, -117.208478</td>
<td>Highway</td>
<td>7465</td>
</tr>
<tr>
<td>San Diego</td>
<td>Sea World Drive</td>
<td>32.770622, -117.204927</td>
<td>32.761817, -117.227897</td>
<td>Sea Drive</td>
<td>2730</td>
</tr>
</tbody>
</table>

### 3) Location relations

Because positions of mobile users and moving objects are continually changing, the location relations between mobile users and moving objects are changing. Changing location relations will affect location-related interactive behaviors between mobile users and moving objects.

Waze shows location relations between mobile users and nearby friends. As shown in Figure 1, a test case is designed to test changing location relations between one mobile user and his friend. In the test case, the friend appears firstly, move closely to the mobile user, and then move far from the mobile user, and disappear at last. So this test case combines all four type of location relations: appearing, approaching, distancing, and disappearing.

### IV. RELATED WORKS

Nowadays, mobile LBS have become one hot research topic in mobile computing domain, and many papers have been published to address different areas in mobile LBS. A conceptual framework for personalized location-based tourism apps leveraging semantic web to enhance tourism experience is proposed by Mahmood [3].

Al Nabhan presents a new strategy in achieving highly reliable and accurate position solutions fulfilling the requirements of Location-Based Services (LBS) pedestrians’ applications [8].

The location privacy issues are serious for LBS. Zhang et al. propose an LBS privacy-quantifying framework and used the mutual information metric to measure adversary’s information gain in his inference attacks [9]. An adaptive location privacy-preserving the system is presented, which allows a user to control the level of privacy disclosure with different quality of location-based services [10].

Freudiger et al use Kullback-Leibler divergence between prior and posterior distributions to measure the ability of the adversary to guess the probability of each user visiting specific POIs [11].
However, there are a few publications about mobile LBS testing. Jerry Gao discusses the issues and difficulties of mobile LBS testing [12]. Ke Zhai proposes a suite of metrics for prioritizing test cases for regression testing of LBS [13]. Nigel Davies proposes a hybrid test and simulation environment for evaluating system- and network-related issues in location-based applications. Hui Chun Chu proposes a two-tier test approach for location-aware mobile learning systems [14]. Solveig Bjørnestad presents an example study about evaluation of a location-based mobile news reader [15]. Jiang Yu analyzes test requirements, and presents a scalable testing framework for mobile LBS [16].

We have proposed an initial test model [17] and some test coverage metrics [18] for function services of mobile LBS. In this paper, we present some test strategies about selecting test devices, location context, location objects, and moving patterns. And then the test approaches are described in details using a case study.

V. CONCLUSION

In this paper, we discuss test approaches and test steps for location-based mobile apps, and some test strategies are proposed about how to select test devices, location contexts, location objects and location-based services, and moving patterns and paths. We also provide a case study to describe our test approaches in details. We hope our approaches are useful for test engineers to design test cases for location-based mobile apps.

ACKNOWLEDGMENTS

This research project was supported by National Natural ScienceFoundation of China (Program No. 61103003).
This research project was supported by Shaanxi Province Industrial Science and Technology Research Foundation (Program No. 2016GY100).

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