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Using Static Analysis and Dalvik ByteCode on Android Compass Applications to detect Operational Anomalies

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Using Static Analysis and Dalvik ByteCode on Android Compass Applications to detect Operational Anomalies

A Senior Project submitted to
The Division of Science, Mathematics, and Computing
of
Bard College

by
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Annandale-on-Hudson, New York
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Abstract

The focus of this paper is the functionality of Android applications and the detection of functional anomalies though a basic static analysis approach. The intention of this research is analyzing applications without running them and detecting how application behavior might correlate with method call patterns. We will focus on simple free compass applications because their ostensible simplicity will make high variation in methods calls an interesting phenomenon. We employ clustering algorithms and other statistical methods to isolate a particularly unusual collection of applications and then perform a qualitative analysis of these applications to discover any interesting common operational behavior or functionality.

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Dedication

To my family and friends.

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Thank You:

To my advisor Robert McGrail who was there every step of the way. Thank you for handing me my first textbook.

To the educators who influenced and guided me: Gretta Tritch Roman, Keith O'Hara, Sven Anderson, G. Ryan Sablosky, Laura Kunreuther, and Lianne Habinek.

To my family, friends, and support system who inspire, challenge, and motivate me.

1
Introduction

1.1 Mobile Lives

Android devices and applications are currently very popular and well sought-after. This is partially because of the various uses these devices have and partially because it's become difficult for one to function in today's world without them. The dependency we have on these devices is fairly recent and so, its not possible to know the impacts our reliance on such technological devices will have. This has always been the case with new developments that allow people to interact with their environment and each other in a new, experimental way. However, someone has always tried to predict what these impacts will be.

Michael L. Dertouzos does just that in his book What Will Be: How the New World of Information Will Change Our Lives, which comes with a foreword from Bill Gates. He expects that "information and technology [will] alter how we work and play but more [importantly, they will] revise deeper aspects of our lives and our humanity and with time, criminals and insurance companies and employers might invade our bank accounts, medical files, and personal correspondences." [21]

His prediction was not far from the truth we see around us today. We use devices that we know can harm our lives in vast ways. We now know that Android devices, as well as others, pose various threats to an average user. These threats exist because Android

supports third-party development with an extensive API that provides applications with access to phone hardware [...and] user data". Despite these threats, users continue to get Android devices and applications. [23]

The way we approach these vulnerabilities, however, speaks to a question whose relevance grows with developments in technology: How do media and technology shape culture and the pursuit of knowledge?

It appears that they inform the kind of knowledge we seek. Culturally we have become a society that is dependent on media and the technological platforms it uses to remain aware of the changing world around us. For this reason, we find ourselves needing to learn more about about them. In doing so, we create new technologies or evolve existing ones to encompass a wider range of functions and offer more security. Like Dertouzos predicted, how we work has been revised. [21]

This effort is exemplified in a paper called Android Permissions Demystified. The research focused on analyzing android applications to see if their developers respected permission requests. They tested this by looking at the permissions an application uses and what parts of a device the application actually accesses. Their findings indicated that "about one-third of the 940 applications tested were overprivlieged," but they also found that this was due to "insufficient API documentation" available for application developers. [23]

Unintentionally, developers accessed user device information they did not have permissions for. Similarly, a lot of users find that their information has been taken without their permission. This forms the basis of our research and the work we chose to do.

We want to investigate how Android applications function and find a way that might allow us to detect functional anomalies within them, if they exist. From this we can generate reports and analyze software in order to better inform the general user and consumer without a hefty knowledge of code on how to approach applications and assess their safety.

1.2 Malware/Android Malware

Malware is a general term for software that aims to damage your device and systems by accessing them and changing them without your permission. Malware can work slowly or abruptly and remain in your systems without your knowledge if it remains in a fixed state. Malware attacks vulnerabilities and weaknesses in code and exploits them causing further damage. Damage, in this sense, could be considered anything that jeopardizes the security of the Operating System (OS). Our focus will be the Android Operating System and Android malware. The security of a device is at times classified or judged by how it fits into the model for a Secure System. [2]

1.3 Secure Systems

The model of a secure system has changed over time but began as the CIA model; which consists of Confidentiality, Integrity, and Availability of a system. Over time, with changes in the forms of computers and programs and expansions in their limits, it expanded to include things like privacy, identification, authentication, authorization, and accountability. For a system to be secure it must try to preserve all of these things. A secure system does this by establishing detective and preventative measures that ensure the security of an operating system. It has structures in place that take these measures in an effort to make sure malware does not access the operating system in a way that the user has not allowed. [32]

1.4 Objective

The aim of our research is to come up with an approach to detect possible functional anomalies which might breach the security of an application by using simple static analysis on the bytecode of these applications.

1.5 Static Analysis

Static Analysis is a technique to detect Malware that has been used in a variety of different ways. It is a method to analyze code and could be considered an observational technique. The thing that separates static analysis from other forms of code analysis is that it is static so it is done before the code is ever run (making it static). Dynamic Analysis is often linked to static analysis but Dynamic Analysis takes place as code is executing. In terms of a secure system, static analysis is the component that is detective and dynamic analysis is the component that is preventative, though they both do not have to be present for our purposes.

Static Analysis is a worthwhile approach here because malware does not immediately present itself. It can, at times, take a dormant form and its danger becomes apparent with its attacks. The technique of detecting the patterns of method calls in malware bytecode allows for patterns and signatures of malware to be seen. Once a pattern is noted, it can be traced in the bytecode of other programs and code. This could also be useful in finding patterns of malware that have not been seen before.

Applying static analysis to new malware can be beneficial in analyzing its new functionality through its bytecode patterns and can inform what the structure of malware would look like. It could also be helpful in detecting remote exploits which is software or a program that takes advantage of a vulnerability already present. It accesses this vulnerability and allows itself permissions and access to your device without your knowledge and consent.

The way we will use bytecode here is by examining bytecode of different application codes and collecting frequency data of the methods invocations. It is important to note that methods are not only used by malware. They are used by all java and dalvik code to run programs. [2]

1.6 Related Work

There have been multiple approaches to securing programs from a wide range of threats and attacks. In the 26th USENIX Security Symposium, a paper, "Oscar: A Practical Page-Permissions-Based Scheme for Thwarting Dangling Pointers", was presented. It focused on free memory and how it opens programs up to the treat of data and control-flow exploits. There have been attack approaches that aim to subvert the control flow of an application. Their approach to address this threat involved using new lock and key mechanisms to prevent the corruption of pointer values that would allow intruders to damage the memory of a web page. [20]

Another paper called, "MAMADROID: Detecting Android Malware" by Building Markov Chains of Behavioral Models, focuses on the creation of a malware detection system for Android that is based on application behaviors. It uses Markov Chains to find features and to classify different threats from an application. A behavioral model was created by considering the sequence of API calls of an application. They used a dataset that included benign and malicious applications and compared their created system to another. [25]

"Android Malware Static Analysis Techniques" is a paper that talks about the callback framework of mobile computing applications and how the architecture of these applications is structured around using callbacks. The use of callbacks is not always specified by the user allowing for the application to perform callbacks and activities without user consent. The approach we will use was precipitated by this information. We decided to focus on analyzing the frequency with which callbacks of methods happen across like applications and what that might indicate about the background functions performed in these applications. [29]

The following Chapters will go through the methods we use to approach our objective, the data we get, an analysis of the data, and the conclusions we come to.

2
Methods

2.1 Approach

Our objective is to analyze free Android-Compatible Compass applications. We will focus on compass applications because of their ostensible simplicity. We then want to use a Static Analysis method to detect patterns of functional anomalies. The approach consists of collecting a set of `.apk` files of Compass applications and extracting their bytecode. Through analyzing the bytecode and comparing the functional patterns of applications, unusual characteristics can be found on specific applications due to their differences from other applications which are intended to function in the same way. Past work indicates that Static Analysis is a classic approach to this and has certain advantages over Dynamic analysis.

Obfuscation is an approach used in code to prevent an application being misused or changed by a third party. Traditionally it is used to protect systems from intruders and others who might want to affect or alter the code in a way that is not authorized by the user. It makes it hard for those without permissions to understand how it functions. [28]

This technique can be used for evil as well as good. Malicious code could be hidden in programs using the same techniques. Hackers and intruders can encrypt their code so an observer cannot find the malware within it. To bypass this, there is a fair degree of

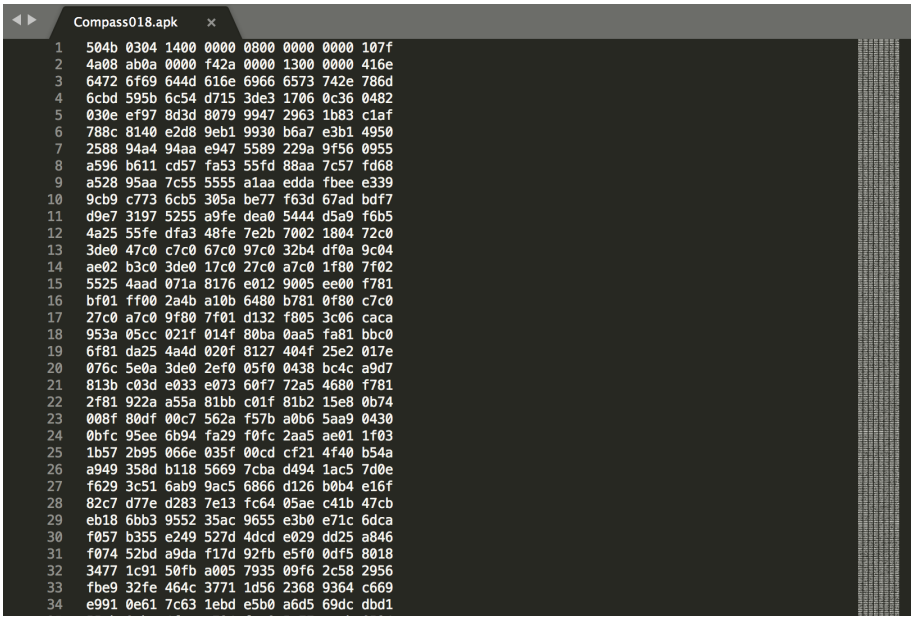


Figure 2.2.1. APK file of Compass Application 18

deobfuscation that must be done. However, a typical user does not know much about the architecture of an application. This makes it imperative to find more ways to ensure that a program is secure before it is released to users. Static Analysis is a safe way of trying to detect these architectural weaknesses but Obfuscation makes it harder to do this with complete guarantee. [28]

2.2 Reverse Engineering

To implement our approach we will use reverse engineer `.dex` files. The source of our reverse engineering is what is known as an APK (Android Package Kit) file. We can decompile an APK file package to get the bytecode of an application and proceed with analysis. Figure 2.2.1 shows what the `.apk` file of a compass application looks like before it is decompiled. Decompiling the file allows us to see its separate parts and presents the code in a way that is readable and free of jargon. This goes well with Static Analysis because we never have to run the code. Reverse engineering provides a target for our static analysis. [19]

2.3 Virtual Machines

An APK file package comes in the format `.apk` and contains the information that make Android mobile applications; these, specifically are run on what is known as the Dalvik Virtual Machine (DVM). Virtual Machines (VM) are simulations of computer Operating Systems (OS). They are built to have the same functionality and operations as a physical computer.

Android applications are typically written in java and are run on a DVM. They are first made of files for the Java Virtual Machine, JVM. Most platforms implement a bytecode interpreter for the JVM. However Android applications are further compiled from JVM code to DVM code. DVM bytecode is stored within a `..dex` exectuable file.

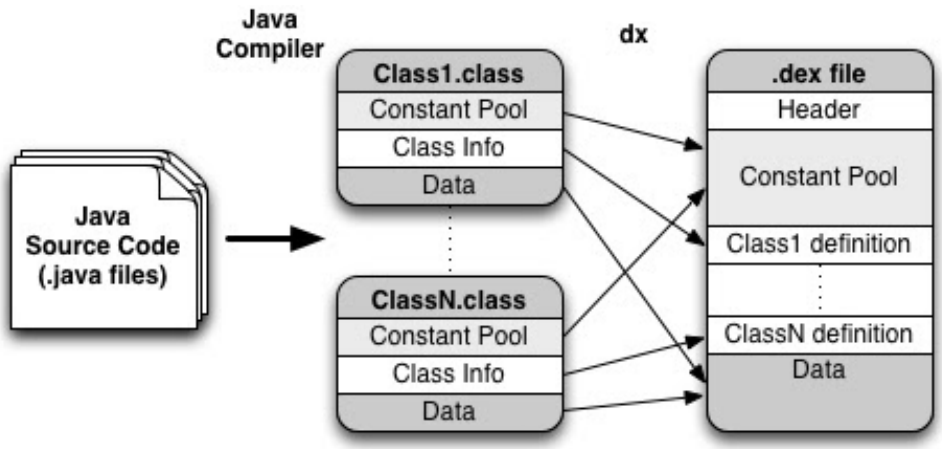


Figure 2.3.1. Java compiler structure [30]

One application can be comprised of multiple, large java files which can be tedious to parse through and analyze. Because these java files are encoded in the `.dex` file format, they can all be run at once on the DVM, and in "mobile applications, a virtual machine is used to test the bytecode of a particular application. Bytecode analysis tests the application behavior and analyzes control and data flow which might be helpful in detecting dangerous functionality performed by malicious applications. Plenty of virtual machine

applications have been implemented for mobile devices, [especially] for android systems. [1]

2.4 Bytecode and Androguard

APKpure is a website that contains apk files of Android applications available for download for free. It allows you to download games, social media applications, and other applications of the sort that can be found in the GooglePlay app store. We use APKpure to gather `.apk` files for compass applications.

Androguard is a python tool. It can be used to decompile apk files and disassemble android apps. It makes the decompiled apk files readable and allows for user experimentation with the files. Along with Python, it is necessary to have IPython and pygments (which provide a shell and syntax highlighting) installed in your operating system. Androguard is an open source tool so it can be downloaded for free as can the python packages mentioned above. The DAD decompiler supported by Androguard is the one we are concerned with. A tool in Androguard (dx) lets all class files convert to a singular `.dex` file. [22]

Bytecode is the instruction set used by applications indicating the processes with which application information is compiled, parsed, and run. It also represents the operation codes for different operands. All of these instructions can be classified into different groups by their function.

2.5 Decompiling With Androguard

To decompile APK files using Androguard tools, they need to be within the Androguard Repository. The most recent version of Androguard is most compatible with Python versions 3+. In most Mac Operating Systems, the built-in Python version is 2.7 so more recent versions of Python must be downloaded to run Androguard [22].

The following code will explain, sequentially, the commands needed to successfully decompile an APK file using the Androguard tool.

```
1.  python3 ./androlyze.py -s
2.  a,d,dx=AnalyzeAPK(/filename/.apk)
```

To start, we use the following commands to first run the androlyze tool in Androguard (1), and then load the selected `.apk` file into it for analysis (2). When using `a,d,dx=AnalyzeAPK`, you are able to access the `.apk` file and the information that comes with it. To access the bytecode needed, we start by getting permissions, application package, and application information using the following commands:

```
1.  a.get_permissions()
2.  a.get_package()
3.  a.get_app_name()
4.  a.get_main_activity()
5.  a.get_activities()
```

The a allows you to get permissions (1), package (2), application name (3), main activity (4), other activities (5), etc. from the `.apk` file package.

We now have access to the information in the `.apk` file but to get the bytecode we need this information to be in DVM Format. This requires reformatting the `.apk` file to a `.dex` file which gives us access to things like the methods, classes, instructions, instruction names, and operands of the file. The following commands convert the `.apk` to DVM format (1), giving us the bytecode. The following command gets the methods used across the application (2) and the number of classes there are across the application(3):

```
1.  d=DalvikVMFormat(a)
2.  d.get_methods()
3.  s=len(d.get_classes())
```

From here, we create a loop to iterate through the classes (1) which allows us to see them and then we get and hold all of the classes in a variable gclasses (2). Now we make

a list, BCinfo, which holds all of the classes from gclasses in a list (3). Then, we create an empty list called results (4), into which we will later append the bytecode data we are interested in. Now, we create another for loop that iterates through the classes in gclasses (5), finds all the methods used across the classes and stores them in a variable methods (6). We create another loop that goes through the methods (7) and gets the instruction calls from the methods storing them in a variable ins (8). We create one last loop that iterates through the instructions in ins (9) and gets their name (10), their operands (11), and appends them to our empty results list (12).

```
1.      for x in range (0, s): d.get_classes()[x].show()
2.      gclasses = d.get_classes()
3.      BCinfo = [x.show() for x in gclasses]
4.      results =[]
5.      for p in gclasses:
6.        methods = p.get_methods()
7.                for method in methods:
8.                    ins= method.get_instructions()
9.                    for i in ins:
10.                       n = i.get_name()
11.                       o = i.get_operands()
12.                       results.append((n, o))
```

Now we can sort the results (1) and by importing Counter Library from the Python collections (2) we can store instruction names and count the number of times they are called in a variable, called counted (3). Then we create a new `.txt` file (4) into which we will write this bytecode information. We create a loop to go through the sorted results (5) and then save these results to the text file we created (6) into two columns holding the instruction names and the number of times they are called:

```
results.sort()
from collections import Counter
counted = Counter([x for (x, y) in results])
with open("/NewFileName/.txt", "w") as f:
    for inst, count in sorted(counted.items())
        f.write("{},{}\n".format(inst, count))
```

The text file created would hold the bytecode information we need. Figure 2.5 shows the `.txt` file of compass application 18. This new file is useful because it provides information that is readable as opposed to the original `.apk` file of this application, which was shown earlier in Figure 2.2.1.

```
add-double,13
add-double/2addr,11
add-float,38
add-float/2addr,149
add-int,158
add-int/2addr,1010
add-int/lit16,24
add-int/lit8,1618
add-long,8
add-long/2addr,38
aget,393
aget-byte,9
aget-char,5
aget-object,322
aget-wide,11
and-int,16
and-int/2addr,90
and-int/lit16,47
and-int/lit8,219
and-long,1
and-long/2addr,38
aput,317
aput-byte,12
aput-object,791
aput-wide,11
array-length,440
check-cast,2387
```

Figure 2.5.1. Snippet of The `.txt` of Compass 18

We use this method on 100 compass application APK files downloaded from APKpure. We create a table to keep track of their source so we can refer back to them if needed. For our simplicity we give the applications number ID's simply by the order they were downloaded. The source information and our formatting information of these files is contained in a master table which can be found in the Appendix.

3
Data

3.1 Consolidation

Upon using Androguard to decompile the `.apk` files of the 100 Compass applications, we now have 100 `.txt` files containing the bytecode information of all the applications. The bytecode information in these files is specifically the virtual machine instructions resulting from compiling the application. These files were saved individually as they were decompiled in Androguard. We create visualizations of the information in these files by consolidating them into one spreadsheet. See Figure 3.1.1

3.2 Focus: invoke-virtual

The instruction we are choosing is invoke-virtual as it might give insight into the ways these applications function on a user's device. As mentioned in the Related Works section of our Introduction, a paper by Suzanna Schmeelk suggests that functions and methods that invoke or rely on callbacks could be indicative of code behaviors that have not been permitted. We focus on invoke-virtual for this reason, applications that need methods to be invoked at a high rate might be representative of functional anomalies. [29]

Compass01			Compass02			Compass03	
add-double	13		add-int/lit8	2		add-double	26
add-double/2add	22		aget-byte	2		add-double/2add	103
add-float	37		aget-object	1		add-float	55
add-float/2addr	142		aput-object	4		add-float/2addr	244
add-int	131		array-length	1		add-int	157
add-int/2addr	703		const-class	2		add-int/2addr	844
add-int/lit16	2		const-string	34		add-int/lit16	12
add-int/lit8	1499		const-wide/16	1		add-int/lit8	1576
add-long	8		const/16	2		add-long	4
add-long/2addr	23		const/4	25		add-long/2addr	49
aget	432		goto	20		aget	545
aget-boolean	1		goto/16	3		aget-boolean	3
aget-byte	5		if-eq	1		aget-byte	19
aget-char	5		if-eqz	14		aget-char	14
aget-object	218		if-ge	2		aget-object	300
aget-wide	3		if-lez	1		aget-short	1
and-int	12		if-lt	1		aget-wide	80
and-int/2addr	82		if-ne	1		and-int	15
and-int/lit16	47		if-nez	3		and-int/2addr	49
and-int/lit8	209		invoke-direct	27		and-int/lit16	51
and-long	1		invoke-static	22		and-int/lit8	158
and-long/2addr	25		invoke-super	2		and-long	2
aput	321		invoke-virtual	92		and-long/2addr	17
aput-boolean	1		monitor-enter	1		aput	418
aput-object	491		monitor-exit	2		aput-boolean	6
aput-wide	3		move	6		aput-byte	8

Figure 3.1.1. Compass Application Information Spreadsheet

The Android source on Dalvik Bytecode explains that, as an instruction, invoke-virtual is used to invoke a normal virtual method (a method that is not private, static, or final, and is also not a constructor) [4]. The instruction invokes method calls across the application, each time it appears, a method in the application classes is called and used. If an application is invoking methods that are not necessary for it to perform its advertised functions than we have reason to believe that the application is performing unknown actions which could be indicators of functional anomalies or a weakness in the application that might harm a user's device. Hence, we choose to focus on the invoke-virtual instruction and the number of times it is called in each application.

Since the instruction we are concerned about is invoke-virtual, we will sort through our spreadsheet (3.1.1), and isolate only the invoke-virtual function and the number of times it is called by each application. Figure (3.2.1) shows this highlighted in pink when invoke-virtual appears.

Compass01	Compass02	Compass03	Compass04	Compass05	Compass06	Compass07	Compass08	Compass09
add-double	add-int/lit8	add-double	add-double	add-double	add-double/2a	add-double	add-double	add-int/lit8
add-double/2a	aget-byte	add-double/2a	add-double/2a	add-double/2a	add-float	add-double/2a	add-double/2a	aget-byte
add-float	aget-object	add-float	add-float	add-float	add-float/2addr	add-float	add-float	aget-object
add-float/2addr	aput-object	add-float/2addr	add-float/2addr	add-float/2addr	add-int	add-float/2addr	add-float/2addr	aput-object
add-int	array-length	add-int	add-int	add-int	add-int/2addr	add-int	add-int	array-length
add-int/2addr	const-class	add-int/2addr	add-int/2addr	add-int/2addr	add-int/lit16	add-int/2addr	add-int/2addr	check-cast
add-int/lit16	const-string	add-int/lit16	add-int/lit16	add-int/lit16	add-int/lit8	add-int/lit16	add-int/lit16	const-class
add-int/lit8	const-wide/16	add-int/lit8	add-int/lit8	add-int/lit8	add-long/2addr	add-int/lit8	add-int/lit8	const-string
add-long	const/16	add-long	add-long	add-long	aget	add-long	add-long	const-wide/16
add-long/2addr	const/4	add-long/2addr	add-long/2addr	add-long/2addr	aget-boolean	add-long/2addr	add-long/2addr	const/16
aget	goto	aget	aget	aget	aget-byte	aget	aget	const/4
aget-boolean	goto/16	aget-boolean	aget-boolean	aget-boolean	aget-object	aget-boolean	aget-boolean	goto
aget-byte	if-eq	aget-byte	aget-byte	aget-byte	aget-wide	aget-byte	aget-byte	goto/16
aget-char	if-eqz	aget-char	aget-char	aget-char	and-int	aget-char	aget-char	if-eq
aget-object	if-ge	aget-object	aget-object	aget-object	and-int/2addr	aget-object	aget-object	if-eqz
aget-wide	if-lez	aget-short	aget-short	aget-short	and-int/lit16	aget-short	aget-short	if-ge
and-int	if-lt	aget-wide	aget-wide	aget-wide	and-int/lit8	aget-wide	aget-wide	if-lez
and-int/2addr	if-ne	and-int	and-int	and-int	and-long/2addr	and-int	and-int	if-lt
and-int/lit16	if-nez	and-int/2addr	and-int/2addr	and-int/2addr	aput	and-int/2addr	and-int/2addr	if-ne
and-int/lit8	invoke-direct	and-int/lit16	and-int/lit16	and-int/lit16	aput-byte	and-int/lit16	and-int/lit16	if-nez
and-long	invoke-static	and-int/lit8	and-int/lit8	and-int/lit8	aput-char	and-int/lit8	and-int/lit8	iget-object
and-long/2addr	invoke-super	and-long	and-long	and-long	aput-object	and-long	and-long	invoke-direct
aput	invoke-virtual	and-long/2addr	and-long/2addr	and-long/2addr	aput-short	and-long/2addr	and-long/2addr	invoke-static
aput-boolean	monitor-enter	aput	aput	aput	array-length	aput	aput	invoke-super
aput-object	monitor-exit	aput-boolean	aput-boolean	aput-boolean	check-cast	aput-boolean	aput-boolean	invoke-virtual

Figure 3.2.1. invoke-virtual in Spreadsheet

From there we can simply create a table where we have the application Name, id number previously assigned, size (MB) of the application and the number of times invoke-virtual is called, See Figure 3.2.2

Compass App Name	Compass App #	File-Size	invoke-virtual
Compass (No Ads)	1	1.9	20239
Classic Compass	2	3.5	92
Compass Steel 3D	3	7.5	26370
Compass	4	3.7	33450
Digital Compass	5	4	33450
Compass	6	1.5	18917
Compass 360 Pro Free	7	5	57593

Figure 3.2.2. Table of application Name, ID, Size (MB), and invoke frequency

From the table displayed in figure 3.2.2 we need to need to make visualizations of this data that groups items by their similarities. Moreover, it needs to implement statistical approach in making these groupings for us to analyze the data.

3.3 Clustering and Mathematica

Creating a cluster is simply creating a scatter plot. But different clustering algortihms exist which let users classify data points and group them in ways that give meaningful

insight into the data. Clusters are based on the similarities data elements have to each other. Two data points are in the same cluster if they are similar and in different clusters if they are not similar.

Figure 3.3.1 shows a simple scatter plot we made with our data points. This is very basic.

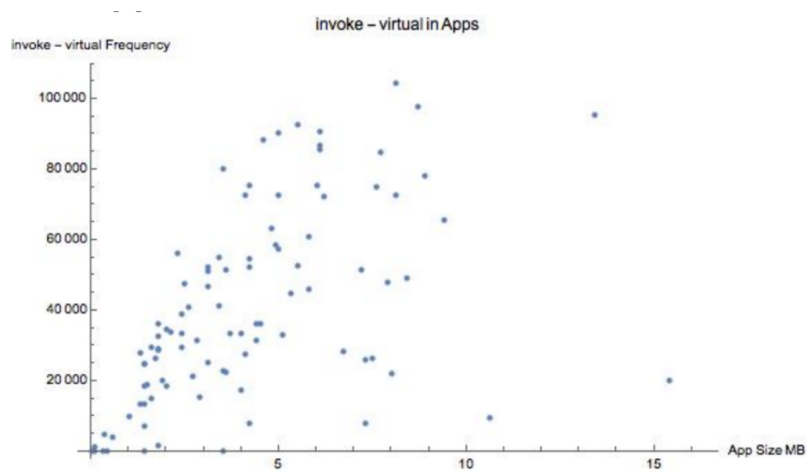


Figure 3.3.1. Scatter Plot of Compass Applications

We can create these clusters using Mathematica; which is a computing system that encompasses a wide range of functions including data analysis and visualizations. In particular, it has built-in clustering algorithms which gives us the option to cluster our data in a number of different ways [26].

One is K-Means Clustering, which is iterative and finds the local maxima through every iteration. The user chooses the number of clusters, K, for their data points. The algorithm starts by randomly assigning a data point to a cluster. It then computes cluster centroids and then reassigns points to cluster centroids closest to it. It iterates through this process, computing cluster centroids, until there are no changes in the cluster formations. Hierarchical Clustering is another example. It is an algorithm that creates clusters based on their hierarchy. Data points are first assigned to individual clusters and then clusters closest to each other are grouped together. These groupings are based on the distance

between clusters and Mathematica allows the option of using different distance functions, like Euclidean distance, or median distance. [31]

There is also the option of using Agglomerate, a hierarchical clustering algorithm which finds clusters by hierarchy, Optimize, which finds clusters by local optimization, GaussianMixture, which finds clusters by variational Gaussian mixture algorithms, MeanShift, which uses the mean-shift clustering algorithm, etc. [24]

3.4 Creating Clusters

We will use the Agglomerate Clustering (heirarchal clustering) method along with a ClusterDissimilarityFunction (which finds clusters and specifies them based on intercluster dissimilarity and distance) to create our clusters.

To create these clusters, we start with a spreadsheet of two columns that only holds the application size (MB) and the number of times it calls invoke-virtual. By turning this into a `.csv` file, and importing it into Mathematica we can start using built in functions that let us create clusters.

We start by making a cluster with the agglomerate algorithm and ClusterDissimilarityFunction (See Figure 3.4.1). We add labels to our cluster data elements to represent the application ID they correspond to for our clarity (See Figure 3.4.2)

In the next section, we will choose specific clusters and data elements of particular interest and analyze them to find indications of functional anomalies, if there are any.

```
(*This imports the table and creates a cluster plot using a ClassDissimilarityFunction
 which specifies the intercluster dissimilarity using the distance from
 clusterian medians*)
w = Import["/Users/cs/Downloads/Compass Apps Data - invoke-virtual.csv"]
r = FindClusters[w, Method → {"Agglomerate", ClusterDissimilarityFunction → "Median"}]
x = ListPlot[r]
```

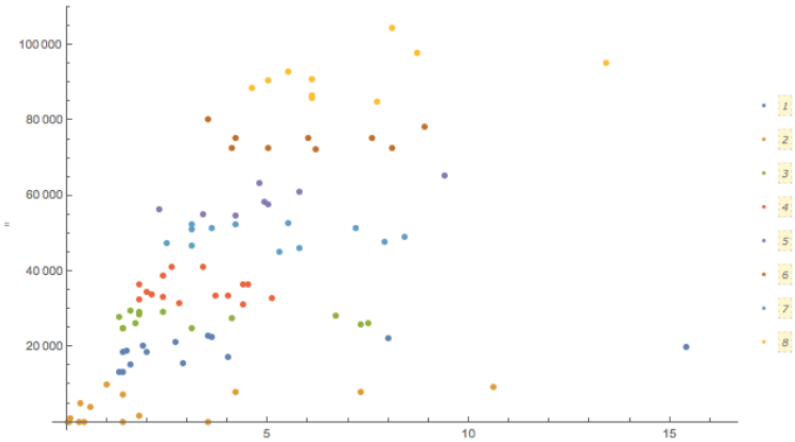


Figure 3.4.1. Clusters from Agglomerate Algorithm and ClusterDissimilarityFunction and Code

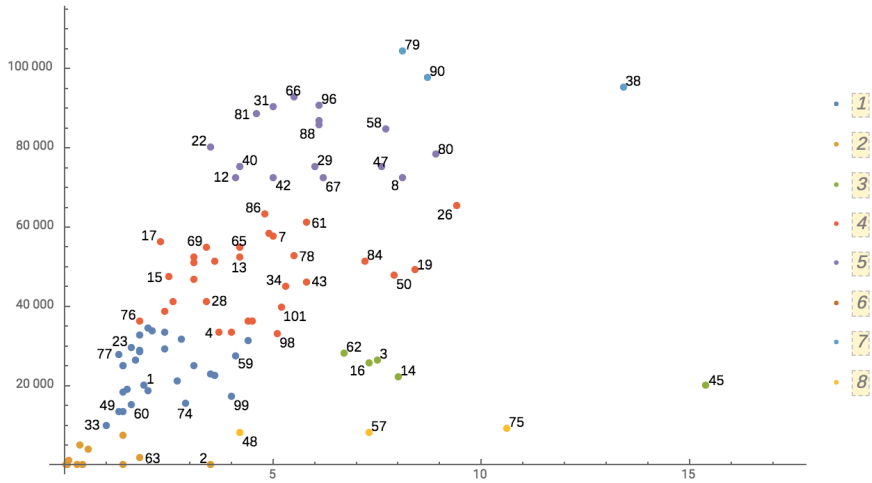


Figure 3.4.2. Clusters from 3.4 with indices Representing Application ID's

4
Analysis

4.1 Clusters of Importance

Our data provides us with eight clusters created using built-in Mathematica clustering algorithms. It is beneficial for us to focus on a specific cluster. We know data elements of a cluster have similar qualities, so we focus two sets of cluster groups that are different from each other and then look at the specific elements in them. In doing so we, set up a comparison that might lead to meaningful conclusions of our data.

This is possible if we use a statistical approach to help us determine which clusters to consider. Clusters of particular interest are those containing applications that are nearly average in size but have an unusually high proportion of method calls. These clusters present themselves to be average in size, however static analysis shows them not to be average at all. Compass, being fairly basic, offers similar functions throughout applications. So, the presence of compass applications that call invoke-virtual at an exceedingly high frequency alongside applications of the same size with average frequencies of calling invoke-virtual indicates that there might be anomalies in applications of this cluster. So, we will compare applications in this cluster to random applications that are in other clusters.

Application Size Average: 5.193726 MB
Application Size Rounded: 5 MB

Application Size Within One MB of The Size Rounded: 4-6 (MB)
Application Sizes That Meet Specifications When Rounded: 3.5-6.4 (MB)

Average Frequency of invoke-virtual: 39,830.6
Standard Deviation: 26,998.4
Average Frequency of invoke-virtual + Standard Deviation: 66,829
Rounded: 67,000

Number of Applications That Meet Specifications: 12
Application ID's: 12, 22, 29, 31, 40, 42, 66, 67, 72, 81, 88, 96
New ID's: A, B, C, D, E, F, G, H, I J, K, L

Number Random Applications Chosen for Comparison: 12
Application ID's: 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54
New ID's: M, N, O, P, Q, R, S, T, U, V, W, X

Figure 4.1.1. Applications to Focus On and Specifications They Must Meet

Figure 4.1.1 shows the specification values that allowed us to isolate applications of interest due to their high frequency of invoke-virtual. We find the average application size (MB) and focus on applications that are within one MB of the rounded average of the application size (5 MB). As the clusters we have are separated horizontally, we will focus on a wider range of the application size instead of restricting ourselves to the mean. So we will look at applications between 4 and 6 MB. Because we round the application sizes to the nearest MB, applications between 3.5 and 6.4 MB will be included in our selection. We also find the average frequency of invoke-virtual from our data set and the standard deviation of the invoke-virtual frequency.

After adding the standard deviation to the mean and rounding it to the nearest whole number we get 67,000, this puts us one standard deviation above the mean. And so we consider applications of frequency greater than 67,000. There are 12 applications from clusters that meet these requirements. We also pick 12 applications at random to compare with these. We assign all 24 applications new letter ID's for simplicity. Figure 4.1.1 also

lists both sets of applications, their initial ID's, and the newly assigned letter ID's they will have.

We now alter our cluster diagram so it displays only these applications. Figure 4.1.2 shows the code implemented in Mathematica to isolate these applications in their clusters and Figure 4.1.3 shows the new cluster plot.

4.2 Application Qualities

We have isolated two groups of applications based on their quantitative characteristics. Figures 4.2.1 and 4.2.2 give us the application Names, ID's (original and new), Size (MB), and invoke-virtual Frequency. We look at their distinct qualitative characteristics to determine what differences or functions the applications in the first cluster group offer that require them to rely on the call back of methods at such a high rate. More so, we look for characteristics which indicate that their functionality doesn't need to rely on call methods. A table with the descriptions of our 24 selected applications written by the publishers of these applications is available in the appendix for reference. We are only going to focus on the qualities and descriptions of applications written by publishers of specific applications. These applications from our selected data will be the focus as they give insight to our research objective.

The qualities we consider in the applications include the Android version, Application Programming Interface (API) level, publish date, latest version, and rating of these applications. These are displayed in Figure 4.2.3, with applications of higher method invocations in gray. This information is provided on APKpure. These qualities show us the development of these applications over time, their caliber, and intelligence. Their functional standard and their capabilities are informed by the Android version and API level that they are compatible with.

```
NotebookDirectory["invoke-virtual.csv"]

w = Import["invoke-virtual.csv"];
new = {};
Table[w[[i]] = {w[[i, 1]], w[[i, 2]]}, {i, 1, Length[w]}];

indices = {12, 22, 29, 31, 40, 42, 66, 67, 72, 81, 88, 96, 43, 44,
   45, 46, 47, 48, 49, 50, 51, 52, 53, 54};
lst = Part[w, indices];

assoc = Association[{}];
Table[assoc[Key[w[[i]]]] = i, {i, 1, Length[w]}];
clusters =
  FindClusters[w,
   Method → {"Agglomerate", ClusterDissimilarityFunction → Median}];
labeled =
 Table[Table[Labeled[clusters[[i]][[j]], assoc[Key[clusters[[i]][[j]]]]],
   {j, 1, Length[clusters[[i]]]}], {i, 1, Length[clusters]}]

x = ListPlot[labeled, PlotLegends → Automatic]
Show[x, ImageSize → Large]

newlabeled =
 Table[Table[Labeled[newclusters[[i]][[j]], assoc[Key[newclusters[[i]][[j]]]]],
   {j, 1, Length[newclusters[[i]]]}], {i, 1, Length[newclusters]}]

newclusters = Table[Intersection[lst, clusters[[i]]],
  {i, 1, Length[clusters]}]

fix = {{{1.3`, 13364}, {1.4`, 13347}, {15.4`, 19953}},
        49             44              45
  {{0.4268`, 115}, {4.2`, 8077}}, {{3.1`, 25056}},
       52              48              51
  {{2.4`, 33358}, {24.1`, 33832}},
       54              53
  {{4.1`, 72588}, {4.2`, 75456}, {5, 72593}, {6, 75353}, {6.2`, 72426},
       12              40            42          29            67
   {7.6`, 75173}}, {{3.1`, 52292}, {5.8`, 46141}, {7.9`, 47911}},
       47              46              43              50
  {{3.5`, 80300}, {4.6`, 88582}, {5, 90554}, {5.5`, 92768},
       22              81            31            66
   {6.1`, 85837}, {6.1`, 86751}, {6.1`, 90770}}}
       88              72              96

x = ListPlot[fix, PlotLegends → Automatic, PlotRange → All]
Show[x, ImageSize → Large]
```

Figure 4.1.2. Mathematica Code used to Isolate Applications

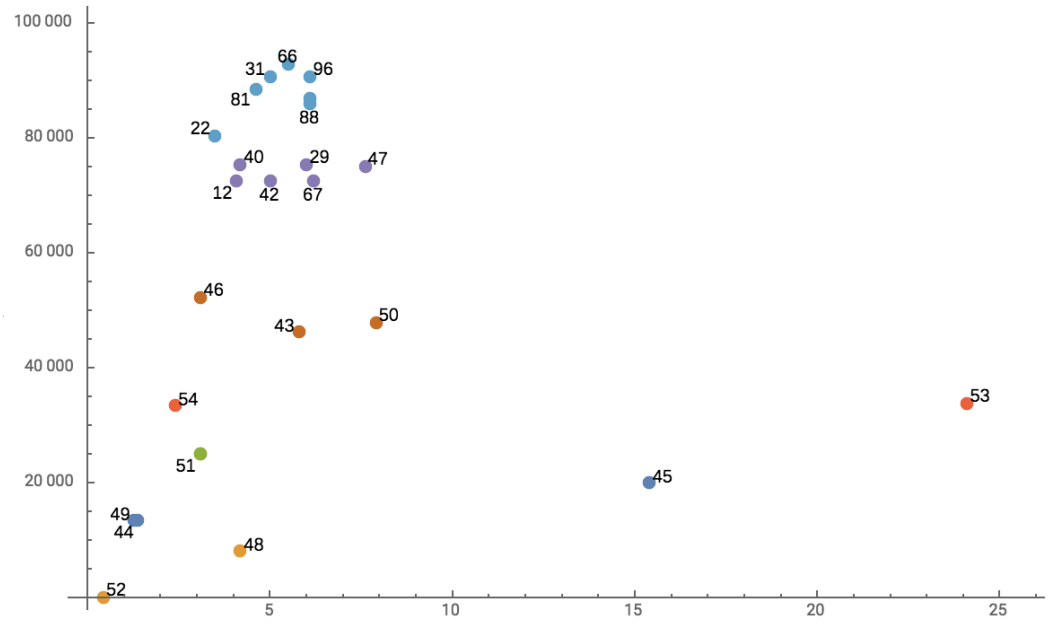


Figure 4.1.3. Clusters to Focus On

Applications One Standard Deviation Above Average Frequency (Size: Approximately 4-6 MB)

Application Name	Compass ID's	Size (MB)	invoke-virtual Frequency
Compass Free	12/ A	4.1	72,588
Color Compass	22/ B	3.5	80,300
Compass	29/ C	6	75,353
Simple Compass	31/ D	5	90,554
🌍 No Ads Compass 🌍	40/ E	4.2	75,456
Compass PRO	42/ F	5	72,593
Compass For Android	66/ G	5.5	92,768
Accurate Compass on Google Map -Compass Navigation	67/ H	6.2	72,426
Compass (Offline)	72/ I	6.1	86,751
Compass	81/ J	4.6	88,582
GPS Compass	88/ K	6.1	85,837
Compass GPS	96/ L	6.1	90,770

Figure 4.2.1. High invoke-virtual Frequency Application Information

Twelve Random Applications:

Application Name	Compass ID's	Size (MB)	invoke-virtual Frequency
Accurate Compass	43/ M	5.8	46,141
Simple Compass	44/ N	1.4	13,347
Military Compass Pro	45/ O	15.4	19,953
Easy Altimeter and Compass	46/ P	3.1	52,292
Best Compass	47/ Q	7.6	75,173
Compass	48/ R	4.2	8,077
Compass- Bubble Level	49/ S	1.3	13,364
Compass - Money Wise	50/ T	7.9	47,911
Compass	51/ U	3.1	25,056
AdFree Compass	52/ V	0.4268	115
Gyro Compass App for Android: True North Direction	53/ W	24.1	33,832
Compass	54/ X	2.4	33,358

Figure 4.2.2. Randomly Selected Application Information

4.3 Android Programming Interface (API)

An API is just a framework that has sets of packages and classes available to Android developers. API level is just a number that specifies the API framework version available with a specific version of Android. Each version has one corresponding API level, both of which increment when updated, these are indicated on Figure 4.3.1. The more updated the version of Android is, the higher the API level is [18]. APIs are updated to include more functionality but they are still compatible with older Android and API versions. At times different components of older API's are "deprecated" which means that they are not recommended for developers to use. This could be because these components are flawed or more efficient versions are available in newer APIs. They are not removed so applications that rely on them can continue to do so. [7]

An application that is newer and uses newer Android versions can perform more functions and use less information and space on a user's device as it is made to be optimized

Application ID, Size, Invoke Frequency, Android Version, API level, Publish Date, Latest Version, and Rating

ID	Size (MB)	Invoke Frequency	Android Version	API level	Publish Date	Latest Version	Rating
A	4.1	72,588	4.0.3+	15 Ice Cream Sandwich MR1	10/18/17	3.9	4.1/5
B	3.5	80,300	4.1+	16 Jelly Bean	10/22/17	0.5.0 (50)	4.6/5
C	6	75,353	4.0.3+	15 Ice Cream Sandwich MR1	1/4/18	1	4.5/5
D	5	90,554	3.0+	11 Honeycomb	10/29/17	45	3.2/5
E	4.2	75,456	4.4+	19 Kitkat	5/19/16	1.11	3.8/5
F	5	72,593	4.0.3+	15 Ice Cream Sandwich MR1	10/17/17	7.48	3.9/5
G	5.5	92,768	4.0.3+	15 Ice Cream Sandwich MR1	8/25/17	1	4.0/5
H	6.2	72,426	4.1+	16 Jelly Bean	3/22/18	1.1	3.7/5
I	6.1	86,751	4.1+	16 Jelly Bean	5/12/17	3	3.2/5
J	4.6	88,582	4.2+	17 Jelly Bean MR1	8/7/17	1.2	4.5/5
K	6.1	85,837	4.1+	16 Jelly Bean	3/5/18	2.28	4.2/5
L	6.1	90,770	4.1+	16 Jelly Bean	3/12/17	1	3.9/5
M	5.8	46,141	4.4+	19 Kitkat	9/27/17	1.13	4.3/5
N	1.4	13,347	4.0.3+	15 Ice Cream Sandwich MR1	9/30/16	1.0.2	3.6/5
O	15.4	19,953	2.3.4+	10 Gingerbread MR1	1/9/18	7	4.1/5
P	3.1	52,292	4.0+	14 Ice Cream Sandwich	9/29/17	2.3.4	4.1/5
Q	7.6	75,173	4.1+	16 Jelly Bean	2/28/18	3.6	3.8/5
R	4.2	8,077	2.2+	8 Froyo	3/12/14	1.5.0	4.1/5
S	1.3	13,364	3.0+	11 Honeycomb	9/23/16	2.0.1	3.9/5
T	7.9	47,911	4.1+	16 Jelly Bean	1/24/17	3.4.2	5/5
U	3.1	25,056	4.4+	19 Kitkat	2/2/18	1.17	4.2/5
V	0.4268	115	2.2+	8 Froyo	5/2/13	1.0.2	4.1/5
W	24.1	33,832	4.1+	16 Jelly Bean	2/3/18	1.1	3.8/5
X	2.4	33,358	4.0.3+	15 Ice Cream Sandwich MR1	2/4/18	1.3	3.7/5

Figure 4.2.3. Application Qualities

with the newer API framework. Android frameworks offer more security as they are upgraded. [27]

We see that applications C, G, L, and H all use API levels 15 and above and are on their first version. This means that they were first made on these high level APIs so it is not a possibility that they are simply adding onto functions they had implemented on a lower API level. These four applications are also from clusters of high invoke-virtual frequency. This is an indication that these applications either offer a wide variety of functions or they are calling methods for reasons unrelated to the functions that they offer.

Platform Codenames, Versions, API Levels, and NDK Releases

The code names match the following version numbers, along with API levels and NDK releases provided for convenience:

Code name	Version	API level
Oreo	8.1.0	API level 27
Oreo	8.0.0	API level 26
Nougat	7.1	API level 25
Nougat	7.0	API level 24
Marshmallow	6.0	API level 23
Lollipop	5.1	API level 22
Lollipop	5.0	API level 21
KitKat	4.4 - 4.4.4	API level 19
Jelly Bean	4.3.x	API level 18
Jelly Bean	4.2.x	API level 17
Jelly Bean	4.1.x	API level 16
Ice Cream Sandwich	4.0.3 - 4.0.4	API level 15, NDK 8
Ice Cream Sandwich	4.0.1 - 4.0.2	API level 14, NDK 7
Honeycomb	3.2.x	API level 13
Honeycomb	3.1	API level 12, NDK 6
Honeycomb	3.0	API level 11
Gingerbread	2.3.3 - 2.3.7	API level 10
Gingerbread	2.3 - 2.3.2	API level 9, NDK 5
Froyo	2.2.x	API level 8, NDK 4

Figure 4.3.1. API's [3]

4.4 Android Sensors

The functions compass applications can offer depends on every application. However, there are sensors on most Android devices which are built into the hardware. Figure 4.4.1 indicates the sensors available for use on devices and the API levels at which they are

offered. It also indicates sensors that they have been deprecated and the API level they were deprecated it. [14]

Figure 4.4.2 divides the different sensor types (hardware and software based) by type. There are motion, environmental, and position sensors [15].

The Motion sensors in Android are the following: Accelerometer (hardware), which follow the orientation and movements (acceleration) of the device. The Gravity Sensor (software), which finds the orientation of the device and indicates direction and magnitude of gravity. The Gyroscope (hardware), measures the movement of the device and gives the rate of rotation. It is used for things that rely on immediate and precise responses to device movement. The Rotation Vector (software) finds the orientation of the device and gives the angle and axis (rotation angle) around which the device is rotated. [10] [9]

The Position Sensors include a Magnetic Field Sensor, which is a digital compass that finds the devices location relative to magnetic north. The Proximity sensor is the distance from the device to an object that is in close proximity. It is used to see if the device is close to the ear. The environment sensors are for environmental properties about the device's surroundings. There is the Light Sensor which finds the ambient light level. The Pressure Sensor finds the air and atmospheric pressure. The Relative Humidity Sensor finds the humidity of the air. The Temperature Sensor finds the ambient air temperature. [9] [8] [13]

4.5 Permissions

If an application offers specialized functions like having a flashlight, or being able to share location to friends or on social media, then it access different software of the device and user data to implement these. In doing so, they would call other methods which are specific to those functions. This indicates that the more complex a compass application is, the more information it accesses from the user's device and calls methods from multiple parts of the Android framework, not just the sensors so it might need to call methods more

Table 2. Sensor availability by platform.

Sensor	Android 4.0 (API Level 14)	Android 2.3 (API Level 9)	Android 2.2 (API Level 8)	Android 1.5 (API Level 3)
TYPE_ACCELEROMETER	Yes	Yes	Yes	Yes
TYPE_AMBIENT_TEMPERATURE	Yes	n/a	n/a	n/a
TYPE_GRAVITY	Yes	Yes	n/a	n/a
TYPE_GYROSCOPE	Yes	Yes	n/a[1]	n/a[1]
TYPE_LIGHT	Yes	Yes	Yes	Yes
TYPE_LINEAR_ACCELERATION	Yes	Yes	n/a	n/a
TYPE_MAGNETIC_FIELD	Yes	Yes	Yes	Yes
TYPE_ORIENTATION	Yes[2]	Yes[2]	Yes[2]	Yes
TYPE_PRESSURE	Yes	Yes	n/a[1]	n/a[1]
TYPE_PROXIMITY	Yes	Yes	Yes	Yes
TYPE_RELATIVE_HUMIDITY	Yes	n/a	n/a	n/a
TYPE_ROTATION_VECTOR	Yes	Yes	n/a	n/a
TYPE_TEMPERATURE	Yes[2]	Yes	Yes	Yes

[1] This sensor type was added in Android 1.5 (API Level 3), but it was not available for use until Android 2.3 (API Level 9).

[2] This sensor is available, but it has been deprecated.

Figure 4.4.1. Sensors Offered And API Levels [14]

Motion Sensors	Environmental Sensors	Position Sensors
1.TYPE_ACCELEROMETER 2.TYPE_ACCELEROMETER_UNCALIBRATED 3.TYPE_GRAVITY 4.TYPE_GYROSCOPE 5.TYPE_GYROSCOPE_UNCALIBRATED 6.TYPE_LINEAR_ACCELERATION 7.TYPE_ROTATION_VECTOR 8.TYPE_SIGNIFICANT_MOTION 9.TYPE_STEP_COUNTER 10.TYPE_STEP_DETECTOR	1.TYPE_AMBIENT_TEMPERATURE 2.TYPE_LIGHT 3.TYPE_PRESSURE 4.TYPE_RELATIVE_HUMIDITY 5.TYPE_TEMPERATURE	1.TYPE_GAME_ROTATION_VECTOR 2.TYPE_GEOMAGNETIC_ROTATION_VECTOR 3.TYPE_MAGNETIC_FIELD 4.TYPE_MAGNETIC_FIELD_UNCALIBRATED 5.TYPE_ORIENTATION 6.TYPE_PROXIMITY

Figure 4.4.2. Sensors by Type

often. To access this information from a user's device, certain permissions must be given to the application.

For an application to access sensitive user data or features like the device camera (if one exists) or the user's photos, permissions must be declared in the manifest file. An application manifest must be included in in every application. This file is required to indicate the application's package name, components of the application, hardware and software features required by the application, and the permissions an application requires to access protected parts of the system or other applications.

However, only dangerous permissions are required in the user agreement. These permissions could be granted at installation of the application or during run-time as these permissions are needed to access sensitive user data. It is up to the developer of the application how they implement these. There are protection levels for permissions indicated by the Android developer framework and the level they exist informs whether or not they need to be requested at run-time of the application. These come in four categories: normal, signature, special, and dangerous. All permissions are for accessing parts of a users device that allows the application to access data existing outside the applications sandbox. Normal permissions are deemed to be of very little risk for to the users privacy. Signature permissions are given at the applications installation time. Special permissions that are deemed sensitive but outside the category of dangerous and normal permissions. Dangerous permissions are those which asks for the user's private information and can alter the user's data and other applications. Users must grant permissions for applications to use dangerous permissions at run time but these must be declared by the application. However, it is up to the application developer to declare these, which they might not. [12] [5] [17] [16] [11]

Figure 4.5.1 indicates permissions and permission groups that have been deemed dangerous by the Android developer framework, including camera, contacts, calendar, location, microphone, phone, sensors, messages, and storage. For a compass application to offer

Permission Group	Permissions
CALENDAR	• READ_CALENDAR • WRITE_CALENDAR
CAMERA	• CAMERA
CONTACTS	• READ_CONTACTS • WRITE_CONTACTS • GET_ACCOUNTS
LOCATION	• ACCESS_FINE_LOCATION • ACCESS_COARSE_LOCATION
MICROPHONE	• RECORD_AUDIO
PHONE	• READ_PHONE_STATE • READ_PHONE_NUMBERS • CALL_PHONE • ANSWER_PHONE_CALLS (*must request at runtime*) • READ_CALL_LOG • WRITE_CALL_LOG • ADD_VOICEMAIL • USE_SIP • PROCESS_OUTGOING_CALLS • ANSWER_PHONE_CALLS
SENSORS	• BODY_SENSORS
SMS	• SEND_SMS • RECEIVE_SMS • READ_SMS • RECEIVE_WAP_PUSH • RECEIVE_MMS
STORAGE	• READ_EXTERNAL_STORAGE • WRITE_EXTERNAL_STORAGE

Figure 4.5.1. Dangerous Permissions and Permission Groups [6]

additional functions that require user information, they use more dangerous permissions which might not always be declared by the developer in the manifest. [6]

These are things one should look out for when downloading an application as some applications are not clear about what user information they access. A user can grant permissions at installation of an application that are dangerous and not know it.

The idea of an applications high frequency of calling invoke-virtual being indicative of an application's irregularity or inferiority to application's of lower invoke-virtual call frequency is supported through the comparison of multiple applications. Applications D, O, and W provide insight here; application D is from the first data grouping, O and W are from the random application grouping. Application D is 5 MB in size, has an invoke-virtual frequency of 90,554, and is of API level 11. O is 15.4 MB in size, invokes methods 19,953 times, and uses API level 10. Application W is 24.1 MB in size, invokes methods 33,832 times, and uses API level 16.

D is called "Simple Compass" and only advertises that it is free and tells the direction the device is facing. It only uses Position Sensors, the magnetometer sensor in particular, which all compass applications must have in order to work. However, it invokes methods the highest amount of times out of the three applications. O and W have the largest file sizes of all 24 applications we are considering but they call invoke-virtual significantly fewer times. The functions they offer explain why they are so large in size.

O is called "Military Compass Pro" and offers a compass, map, military and offline navigation, sun phases based on location, distance from locations, current locations, time, date, etc. It allows the user to backup and load locations as well as share locations. It also allows users to send messages and mark their location and it can be used when the user is offline. Similarly, W is called the Gyro Compass and it uses the Gyroscope, Altimeter, and Magnetometer Sensors. It also declares that it uses them with complete transparency. It claims to have an "insanely beautiful" user interface and be 3D. It allows the user to "determine the directions, elevation, navigation, orientation, coordinates, current location quickly & accurately" and can work globally.

Both O and W use multiple sensor types and external device and application data. Their expansive functions and need to store data on the users device explain their size. Application D invokes methods significantly more times in comparison despite being compatible with a higher level API than application O. It is unclear what background functions D is conducting but due to its invoke-virtual frequency we suspect that there are other tasks it is conducting unknown to the user.

4.6 Applications of Particular Interest

As we go through the descriptions of applications written by application developers we find an interesting correlation between application A and F.

Application A is of size 4.1 MB and F has size 5 MB. They are both applications of the first data grouping, calling invoke-virtual 72,588 and 72,593 times, respectively. They

are both compatible with Android version 4.0.3+ and are of API level 15. The interesting thing we notice is that these applications were posted one day apart from each other; A on October 18th, 2017 and F on October 17th, 2017. The difference in their invoke-virtual frequency is only 5. The similarities of these applications increase when we look at their qualitative data.

Figure 4.6.1 shows the description posted by PRO Compass, the author of Application A (Compass Free) and Figure 4.6.2 shows the description posted by Mobile Essentials, the author of Application F (Compass PRO). We notice that their format and description are nearly identical. There are sections of their descriptions that overlap verbatim. Figures have highlighted the similarities between both application descriptions in blue.

There is one inconsistency that makes these applications stand out. In the description of Application A, called Compass Free, it states PRO Compass shows direction of north. The name of the application A is written as the name of application B, which was published one day earlier. It is clear that these applications are the same and published by two different authors, or by the same person with two different accounts. They have minor changes to prevent the detection of their similarities. Furthermore, the user interface of these two applications is also very similar in format with minor changes that distinguish them. Figures 4.6.3 and 4.6.4 show the visuals provided of both applications on APKpure.

When we look further into the authors of these applications we find that the author of application A has only posted one other application and it was on the same date as application A. This is a flashlight application called Flashlight Free and it is 5.4 MB in size. The author of application F has posted a total of 13 applications, 11 of which were posted on the same date as F. One of these applications is called Flashlight LED and is of size 4.9 MB. This indicates that these two flashlight applications posted by these authors might also be the same applications posted with different names and visuals. Just as with applications A and F, these applications have descriptions and user interfaces that are

A **The description of Compass Free**

** Use just like a real compass. (Hold your Android flat!) **

** Your device must have MAGNETIC SENSOR inside to read earth magnetic field. If your device does not have magnetic sensor Compass Free or any other compass app will not work. PLEASE DON'T WRITE BAD COMMENTS, IT'S NOT OUR FAULT! **

Compass Free is essential app for your Android device. It is a professional compass in your pocket, when you need it, where you need it and you never know when I might come handy. PRO Compass shows direction of north, south, east and west, shows degrees in "side window", has rotating bezel for advanced compass navigation.

How to use Compass?

First we'll need to cover a little bit of compass jargon first. The part of Compass that moves and always points north is called the card (with N,S,E, and W indicated, and a beveled edge with a series of numbers on it). There is a movable ring around the edge of the compass, called the bezel. A red double line across the top of the compass is called the lubber line, and finally, there is a little window above the compass which is often named as side-window (as it is on the side of a real compass).

Side-window navigation couldn't be simpler. You point the lubber line on top of your compass at where you want to go. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you're going, you should always see the same number in your window as long as you're going the right way. If you see a different number, turn until you see the same number.

The downside of the side window method is that you need to remember your number.

Navigating with bezel works essentially the same as using the side window, but your bezel remembers your number for you. All you do is, point the lubber line on top of your compass at where you want to go, and then wait until the card settles down and stops moving. Then turn your bezel until the double triangle on the edge of the bezel (the notch right by the number zero on the bezel) is bracketing the north arrow on the card. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you're going, you should always see the north arrow inside the notch, as long as you're going the right way. If not, turn until you see the north arrow inside the notch.

Notice that if you've adjusted the bezel correctly, the number in the side window is also the number directly across from you at the front end of the lubber line. In other words, if you turned the bezel counterclockwise until the notch bracketed the north arrow, the 120 on the bezel would be at the far end of the lubber line. Notice that on the card, the number showing in the side window is 120. If you were holding this compass and going in the direction of the lubber line, you'd be on a heading of 120.

Now you should have learned how to go to desired direction. But how do you get back? Easy! If you're thinking in terms of the bezel, simply turn until the north arrow faces not to the notch, but to the single triangle that's exactly across from the notch. Now you're pointed back where you came.

The really tricky part of using your compass isn't learning what the numbers mean and how to adjust the bezel. The most common mistakes are not holding your compass flat, and not actually going in the direction your lubber line is pointing.

Large iron and steel objects can influence the magnetic sensor in your Android device, causing it to point in the wrong direction. This is called deviation. If you suspect this is happening, simply move away from the object several feet and the problem should correct itself.

Other features or Compass Free app:

- Simple to use, use it like a real compass
- Design with functionality in mind (easy to read, lower battery consumption due to black color used)
- Large numbers and large rotating bezel
- Professional and optimized coding to keep application size as small as possible
- It's FREE

Figure 4.6.1. Description of Compass Free

F **The description of Compass PRO**

****IMPORTANT:Calibrate your device by moving it in figure 8 pattern before each use to ensure compass is accurate (this will calibrate it against magnetic interference). Hold your device flat, use just like a real compass.**** Compass PRO is the compass in your pocket, when you need it, where you need it.

Compass PRO has the following functions:

- Shows direction of north, south, east and west
- Shows degrees in "side window"
- Rotating bezel

HOW TO USE COMPASS PRO?

First we'll need to cover a little bit of compass jargon first. The part of Compass PRO that moves and always points north is called the card (with N,S,E, and W indicated, and a beveled edge with a series of numbers on it). There is a movable ring around the edge of the compass, called the bezel. A red double line across the top of the compass is called the lubber line, and finally, there is a little window above the compass which is often named as side-window (as it is on the side of a real compass).

Side-window navigation couldn't be simpler. You point the lubber line on top of your compass at where you want to go. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you're going, you should always see the same number in your window as long as you're going the right way. If you see a different number, turn until you see the same number.

The downside of the side window method is that you need to remember your number.

Navigating with bezel works essentially the same as using the side window, but your bezel remembers your number for you. All you do is, point the lubber line on top of your compass at where you want to go, and then wait until the card settles down and stops moving. Then turn your bezel until the double triangle on the edge of the bezel (the notch right by the number zero on the bezel) is bracketing the north arrow on the card. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you're going, you should always see the north arrow inside the notch, as long as you're going the right way. If not, turn until you see the north arrow inside the notch.

Notice that if you've adjusted the bezel correctly, the number in the side window is also the number directly across from you at the front end of the lubber line. In other words, if you turned the bezel counterclockwise until the notch bracketed the north arrow, the 120 on the bezel would be at the far end of the lubber line. Notice that on the card, the number showing in the side window is 120. If you were holding this compass and going in the direction of the lubber line, you'd be on a heading of 120.

Now you should have learned how to go to desired direction. But how do you get back? Easy! If you're thinking in terms of the bezel, simply turn until the north arrow faces not to the notch, but to the single triangle that's exactly across from the notch. Now you're pointed back where you came.

The really tricky part of using your compass isn't learning what the numbers mean and how to adjust the bezel. The most common mistakes are not holding your compass flat, and not actually going in the direction your lubber line is pointing.

Large iron and steel objects can influence the magnetic sensor in your Android device, causing it to point in the wrong direction. This is called deviation. If you suspect this is happening, simply move away from the object several feet and the problem should correct itself.

Other features:

- Simple to use, use it like a real compass
- Professional design
- Large numbers and large rotating bezel
- Audio Effects on rotating bezel
- Incredibly smooth movements
- Professional and optimized coding to keep application size as small as possible
- It's FREE

Figure 4.6.2. Description of Compass PRO

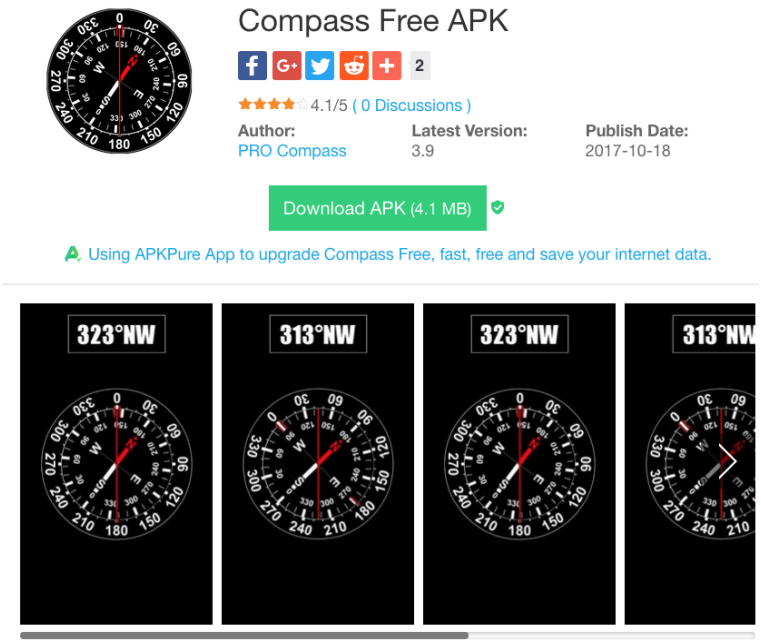


Figure 4.6.3. Application A User Interface

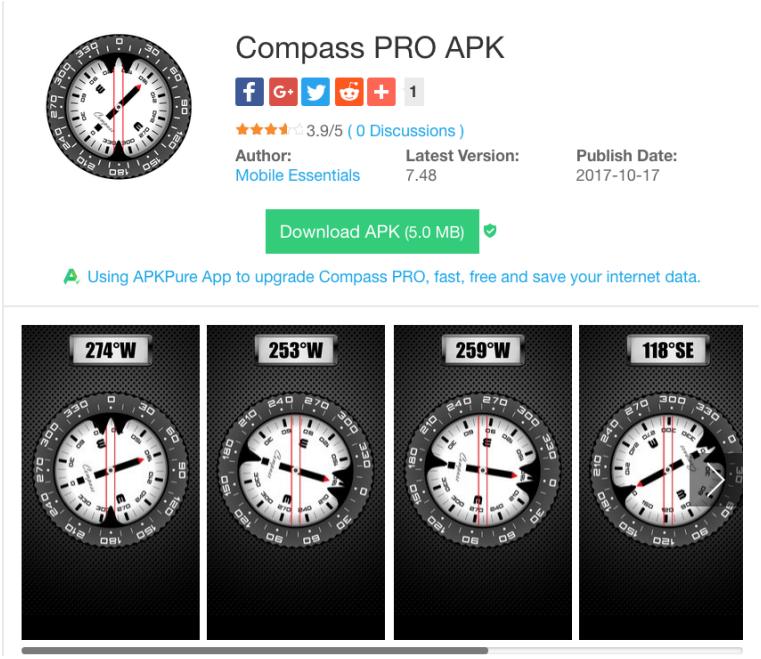


Figure 4.6.4. Application F User Interface

nearly identical. Figures 4.6.5 and 4.6.7 show images of their user interfaces. Figures 4.6.6 and 4.6.8 show their descriptions.

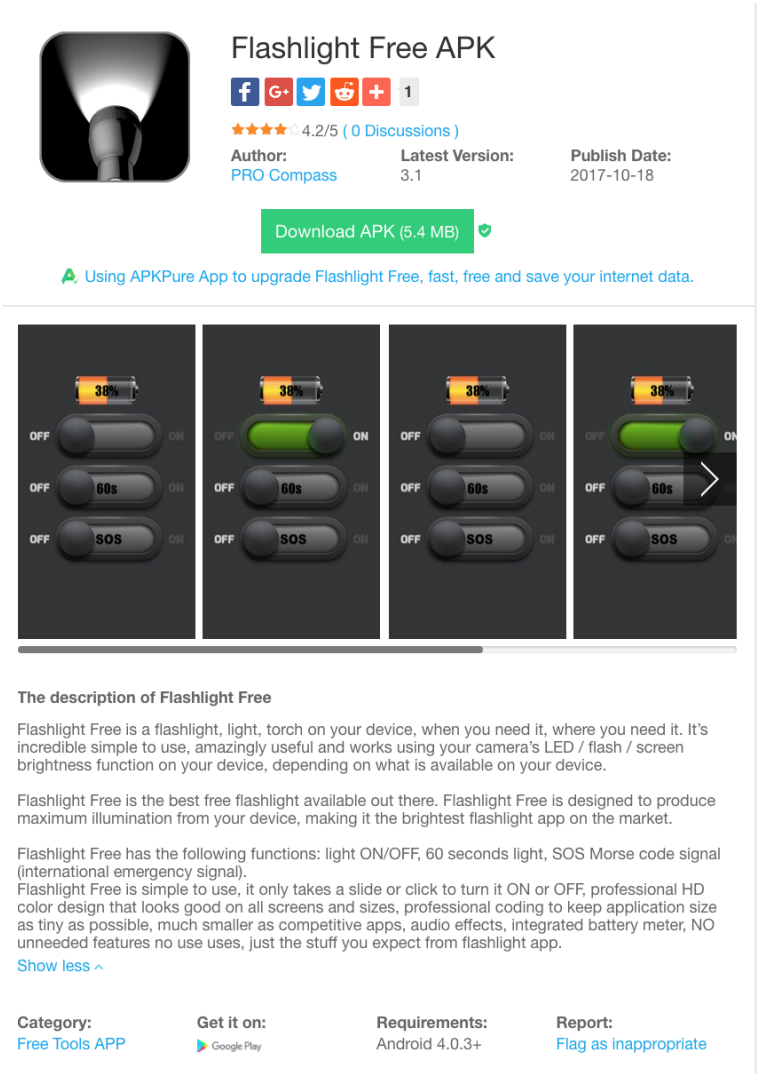


Figure 4.6.5. Flashlight Free User Interface (Same Author as Application A)

4.7 Data Mining and Copyright Concerns

When comparing to other Applications offering the same functionality, it seems that the more basic the functions of an application are, the smaller the size should be. It is also indicated, once again, that the more updated a version of an application is, the higher the API level it is built in makes it more secure, especially when it is an application that offers

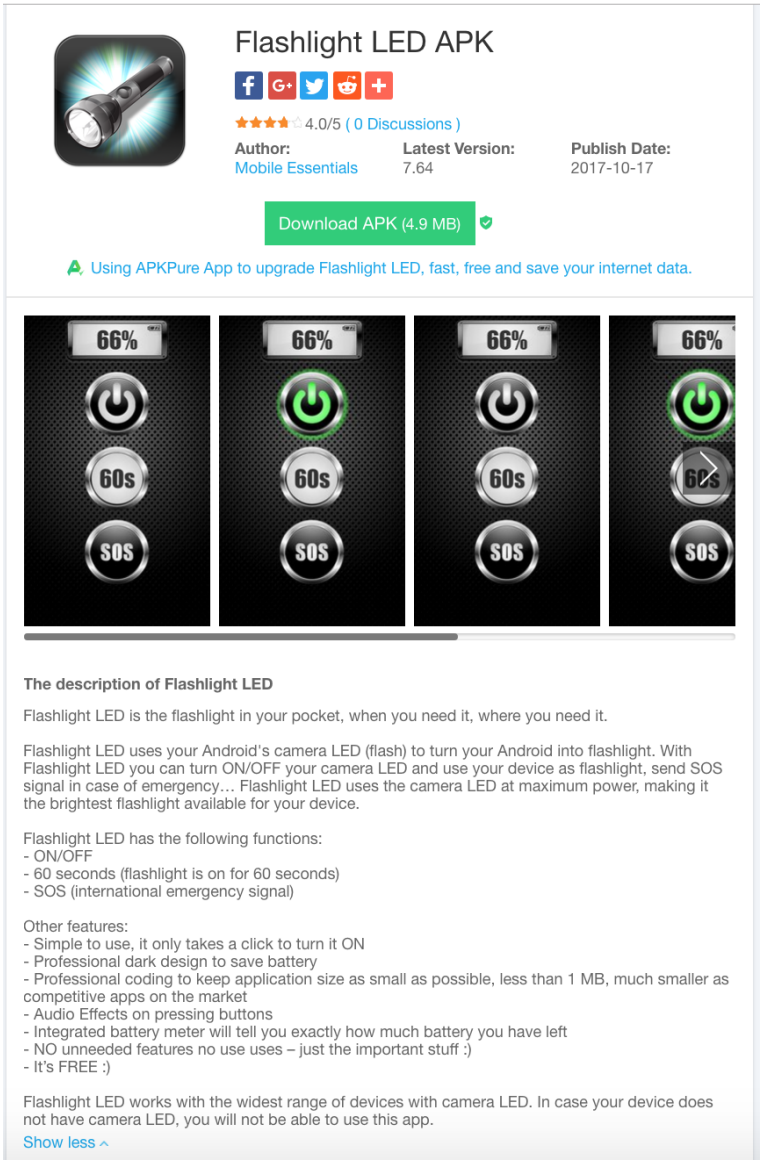


Figure 4.6.6. Flashlight LED User Interface (Same Author as Application F)

The description of Flashlight Free

Flashlight Free is a flashlight, light, torch on your device, when you need it, where you need it. It's incredible simple to use, amazingly useful and works using your camera's LED / flash / screen brightness function on your device, depending on what is available on your device.

Flashlight Free is the best free flashlight available out there. Flashlight Free is designed to produce maximum illumination from your device, making it the brightest flashlight app on the market.

Flashlight Free has the following functions: light ON/OFF, 60 seconds light, SOS Morse code signal (international emergency signal).
Flashlight Free is simple to use, it only takes a slide or click to turn it ON or OFF, professional HD color design that looks good on all screens and sizes, professional coding to keep application size as tiny as possible, much smaller as competitive apps, audio effects, integrated battery meter, NO unneeded features no use uses, just the stuff you expect from flashlight app.

Figure 4.6.7. Flashlight Free Description (Same Author as Application A)

The description of Flashlight LED

Flashlight LED is the flashlight in your pocket, when you need it, where you need it.

Flashlight LED uses your Android's camera LED (flash) to turn your Android into flashlight. With Flashlight LED you can turn ON/OFF your camera LED and use your device as flashlight, send SOS signal in case of emergency… Flashlight LED uses the camera LED at maximum power, making it the brightest flashlight available for your device.

Flashlight LED has the following functions:
- ON/OFF
- 60 seconds (flashlight is on for 60 seconds)
- SOS (international emergency signal)

Other features:
- Simple to use, it only takes a click to turn it ON
- Professional dark design to save battery
- Professional coding to keep application size as small as possible, less than 1 MB, much smaller as competitive apps on the market
- Audio Effects on pressing buttons
- Integrated battery meter will tell you exactly how much battery you have left
- NO unneeded features no use uses – just the important stuff :)
- It's FREE :)

Flashlight LED works with the widest range of devices with camera LED. In case your device does not have camera LED, you will not be able to use this app.

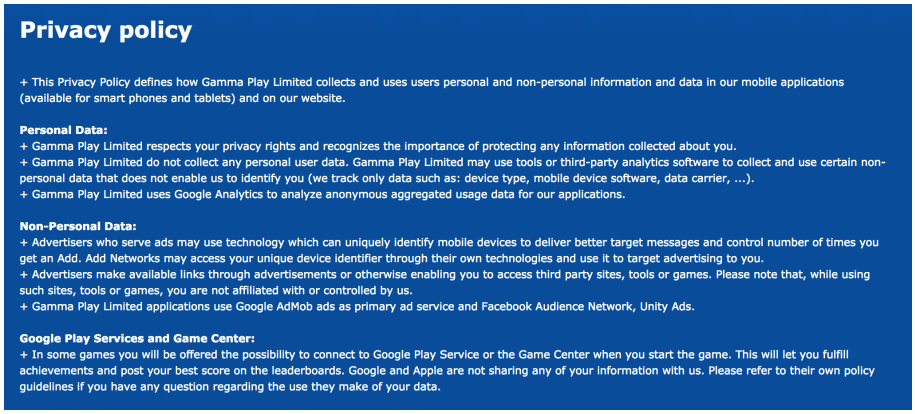
Figure 4.6.8. Flashlight LED Description (Same Author as Application F)

more complex functions and utilizes multiple built in features of the Android framework, be it software or network based. Users should use these two methods of analyzing applications before installing them to their device. The similarities between A and F as well as the flashlight applications published by the same authors leads us to question what the intention of the authors, if they are separate individuals, or author, if it is the same person, is in publishing the same applications.

When we look further we can also find these applications by the same authors on the Google Play Store as APKpure provides the same applications but for free. These applications are also free on the Google Play Store. The notable thing is that application A has been downloaded 27,907 times on the Google Play Store and application F has been downloaded 67,692 times. This comes to a total of 95,599 downloads. The flashlight application from the author of application A has been downloaded 585 times and the flashlight application by the author of application F has been downloaded 3,257 coming to a total of 3,842 downloads.

By uploading the applications on the various platforms with the various authors the number of users reached just by the compass application is 95,5999. The flashlight application was downloaded by 3,842 times just on the Google Play Store.

To see if the authors had any connection we looked at the developer information of these applications on the Google Play Store and they are different for A and F, A having the an e-mail `procompassapp@gmail.com` and F having the email `androidshortcuts@gmail.com`. But by checking the privacy policies of both developers we are led to a website about an application publishing and development company called "GAMMA PLAY". It is copyrighted as `2017 Gamma Play` and invites developers to contact them if they would like to publish a game or application under this developer. Its web-page is singular and only contains its privacy policy pictured in Figure 4.7.1. The privacy policy explains the ways in which the user's personal and private (phrased "non-personal") information and data is used in their mobile applications. They claim to respect privacy rights and do not not collect personal user data but "may use tools or third-party analytic software to collect and use certain non-personal data that does not enable us to identify you (we track only data such as: device type, mobile device software, data carrier, ...)". For "non-personal data" they mention that advertisers may use this information to identify devices to "deliver better target messages and control number of times [a user] gets an Add [sic]". These advertisers also "make available links through advertisements or otherwise enabling [the users] to access third party sites, tools or games". Gamma Play makes a point to state that advertisers use "non-personal" data and that users are not "not affiliated with or controlled by" it.



Privacy policy

+ This Privacy Policy defines how Gamma Play Limited collects and uses users personal and non-personal information and data in our mobile applications (available for smart phones and tablets) and on our website.

Personal Data:
+ Gamma Play Limited respects your privacy rights and recognizes the importance of protecting any information collected about you.
+ Gamma Play Limited do not collect any personal user data. Gamma Play Limited may use tools or third-party analytics software to collect and use certain non-personal data that does not enable us to identify you (we track only data such as: device type, mobile device software, data carrier, ...).
+ Gamma Play Limited uses Google Analytics to analyze anonymous aggregated usage data for our applications.

Non-Personal Data:
+ Advertisers who serve ads may use technology which can uniquely identify mobile devices to deliver better target messages and control number of times you get an Add. Add Networks may access your unique device identifier through their own technologies and use it to target advertising to you.
+ Advertisers make available links through advertisements or otherwise enabling you to access third party sites, tools or games. Please note that, while using such sites, tools or games, you are not affiliated with or controlled by us.
+ Gamma Play Limited applications use Google AdMob ads as primary ad service and Facebook Audience Network, Unity Ads.

Google Play Services and Game Center:
+ In some games you will be offered the possibility to connect to Google Play Service or the Game Center when you start the game. This will let you fulfill achievements and post your best score on the leaderboards. Google and Apple are not sharing any of your information with us. Please refer to their own policy guidelines if you have any question regarding the use they make of your data.

Figure 4.7.1. Gamma Play Privacy Policy

We can say for sure that these applications are suspicious since they have been repeatedly posted, but we can only infer what their intention is.

5
Conclusion

5.1 Interpretation

The fact that these applications, and all others by both authors, have been uploaded on two different websites where a user can download them for free lets us come to different conclusions about what the intentions of these developer(s) might be. It could be that these applications exist for data mining purposes, getting as much user data as they can. By doing so, they endanger user privacy with no indication of exactly what information they are accessing on a user's device. Their descriptions are filled with jargon and indicate that the only function they really offer is allowing the user to see the general compass direction which only uses one sensor type on devices. This is with the assumption that it is the same publisher or developer posting these applications.

If we assume that it is different people then the concern becomes copyright violations. If two different publishers are posting the same applications then one must have been taken and adapted very slightly and posted by another. This is dangerous to all developers and application creators.

Using a static analysis approach we have been able to find functional anomalies on applications by looking at their bytecode quantitatively. By adding a qualitative approach we have been able to find functional anomalies that we predicted. We can only infer what

these anomalies are but it is promising that with a growing data set we can identify more qualities of applications that indicate dishonesty and vulnerabilities.

Appendix A

Appendices

	Descriptions of Compass Applications Written by Application Publishers on APKpure Verbatim:
ID	Description
A	**The description of Compass Free** ** Use just like a real compass. (Hold your Android flat!) ** ** Your device must have MAGNETIC SENSOR inside to read earth magnetic field. If your device does not have magnetic sensor Compass Free or any other compass app will not work. PLEASE DON'T WRITE BAD COMMENTS, IT'S NOT OUR FAULT! ** Compass Free is essential app for your Android device. It is a professional compass in your pocket, when you need it, where you need it and you never know when I might come handy. PRO Compass shows direction of north, south, east and west, shows degrees in "side window", has rotating bezel for advanced compass navigation. How to use Compass? First we'll need to cover a little bit of compass jargon first. The part of Compass that moves and always points north is called the card (with N,S,E, and W indicated, and a beveled edge with a series of numbers on it). There is a movable ring around the edge of the compass, called the bezel. A red double line across the top of the compass is called the lubber line, and finally, there is a little window above the compass which is often named as side-window (as it is on the side of a real compass). Side-window navigation couldn't be simpler. You point the lubber line on top of your compass at where you want to go. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you're going, you should always see the same number in your window as long as you're going the right way. If you see a different number, turn until you see the same number. The downside of the side window method is that you need to remember your number. Navigating with bezel works essentially the same as using the side window, but your bezel remembers your number for you. All you do is, point the lubber line on top of your compass at where you want to go, and then wait until the card settles down and stops moving. Then turn your bezel until the double triangle on the edge of the bezel (the notch right by the number zero on the bezel) is bracketing the north arrow on the card. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you're going, you should always see the north arrow inside the notch, as long as you're going the right way. If not, turn until you see the north arrow inside the notch. Notice that if you've adjusted the bezel correctly, the number in the side window is also the number directly across from you at the front end of the lubber line. In other words, if you turned the bezel counterclockwise until the notch bracketed the north arrow, the 120 on the bezel would be at the far end of the lubber line. Notice that on the card, the number showing in the side window is 120. If you were holding this compass and going in the direction of the lubber line, you'd be on a heading of 120. Now you should have learned how to go to desired direction. But how do you get back? Easy! If you're thinking in terms of the bezel, simply turn until the north arrow faces not to the notch, but to the single triangle that's exactly across from the notch. Now you're pointed back where you came. The really tricky part of using your compass isn't learning what the numbers mean and how to adjust the bezel. The most common mistakes are not holding your compass flat, and not actually going in the direction your lubber line is pointing. Large iron and steel objects can influence the magnetic sensor in your Android device, causing it to point in the wrong direction. This is called deviation. If you suspect this is happening, simply move away from the object several feet and the problem should correct itself.

	Other features or Compass Free app: - Simple to use, use it like a real compass - Design with functionality in mind (easy to read, lower battery consumption due to black color used) - Large numbers and large rotating bezel - Professional and optimized coding to keep application size as small as possible - It's FREE
B	**The description of Color Compass** **Smart compass free.** **Hiking compass sos flashlight.** **★ Easy calibration** **★ Show angle in degrees** **★ Small size** **★ Clean design** **★ Install on SD** **★ SOS FlashLight** **★ Night mode** - This is a simple but high precision digital compass. - This is a minimal and beautiful compass. - you can`t lost yourself when you get a new place. - A really beautiful **Clock** with hours , minutes, seconds, week and date. - It has beautiful, pure and practical UI design. - It has a lot of **Skin** that you can get all by free. - It has a **Flashlight**, you use it when you walk in night. - It has a **SOS** function, you can use it on your outdoor activity. **How to use:** - Keep your phone parallel to the ground and turned toward the red arrow that you want to define - Compass will display on-screen directions and degrees. - You can change the screen brightness by slide up or down on the screen, so that you can use it more comfortable. *** Note:** *** Your mobile device must have a compass sensor can use this application. *** Keep the device away from metal objects, machinery and where high magnetic field to avoid false results Applications compass, digital compass to help you determine the direction quickly and accurately. *** You can move your phone in space in a ∞ figure pattern until the accuracy turns to high.

	*** If you do not have a compass sensor, you will not be able to run Compass and that is not our fault, do not underestimate us on the google play store. - N is north - S is the South - E is east - W is the West - NE is North-East - SE is the Southeast - SW is southwest - NW is northwest.
C	**The description of Compass** Compass app uses just like a real compass. Use it on camping trips, to navigate in unknown territory or when you get lost. Features of Compass ● Compass ● Display latitude, longitude and altitude ● Display north, south, east and west ● High precision ● Easy calibration ● Small size ● Clean design ● Incredibly smooth movements ● No internet connection required Note: Your device must have MAGNETIC SENSOR inside to read earth magnetic field. If your device does not have magnetic sensor Compass Free or any other compass app will not work. PLEASE DON'T WRITE BAD COMMENTS, IT'S NOT OUR FAULT
D	**The description of Simple Compass** This Compass application is free! Simple Compass application can be used for your outdoor activities. (Travel, Hiking, Camping, Picnics....) Anytime & anywhere check the compass pointing direction!! ※ If the compass pointing direction of application is error, Please move the device in a figure 8 pattern & rotate around all axes.
E	**The description of 🌍 No Ads Compass 🌍** No Ads Compass

	Cool and lightweight compass with material design - Lightweight - No Ads No Ads Apps! All of our apps are with no ads
F	**The description of Compass PRO** ****IMPORTANT:Calibrate your device by moving it in figure 8 pattern before each use to ensure compass is accurate (this will calibrate it against magnetic interference). Hold your device flat, use just like a real compass.**** Compass PRO is the compass in your pocket, when you need it, where you need it. Compass PRO has the following functions: - Shows direction of north, south, east and west - Shows degrees in “side window” - Rotating bezel ---------- HOW TO USE COMPASS PRO? First we’ll need to cover a little bit of compass jargon first. The part of Compass PRO that moves and always points north is called the card (with N,S,E, and W indicated, and a beveled edge with a series of numbers on it). There is a movable ring around the edge of the compass, called the bezel. A red double line across the top of the compass is called the lubber line, and finally, there is a little window above the compass which is often named as side-window (as it is on the side of a real compass). Side-window navigation couldn’t be simpler. You point the lubber line on top of your compass at where you want to go. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you’re going, you should always see the same number in your window as long as you’re going the right way. If you see a different number, turn until you see the same number. The downside of the side window method is that you need to remember your number. Navigating with bezel works essentially the same as using the side window, but your bezel remembers your number for you. All you do is, point the lubber line on top of your compass at where you want to go, and then wait until the card settles down and stops moving. Then turn your bezel until the double triangle on the edge of the bezel (the notch right by the number zero on the bezel) is bracketing the north arrow on the card. Now as long as you hold your compass flat in front of you with the lubber line pointing in the direction you’re going, you should always see the north arrow inside the notch, as long as you’re going the right way. If not, turn until you see the north arrow inside the notch. Notice that if you’ve adjusted the bezel correctly, the number in the side window is also the number directly across from you at the front end of the lubber line. In other words, if you turned the bezel counterclockwise until the notch bracketed the north arrow, the 120 on the bezel would be at the far end of the lubber line. Notice that on the card, the number showing in the side window is 120. If you were holding this compass and going in the direction of the lubber line, you’d be on a heading of 120. Now you should have learned how to go to desired direction. But how do you get back? Easy! If you’re thinking in terms of the bezel, simply turn until the north arrow faces not to the notch, but to the single triangle that’s exactly across from the notch. Now you’re pointed back where you came. The really tricky part of using your compass isn’t learning what the numbers mean and how to adjust the bezel. The most common mistakes are not holding your compass flat, and not actually going in the direction your lubber line is pointing. Large iron and steel objects can influence the magnetic sensor in your Android device, causing it to point in the wrong direction.

	This is called deviation. If you suspect this is happening, simply move away from the object several feet and the problem should correct itself. ---------- Other features: - Simple to use, use it like a real compass - Professional design - Large numbers and large rotating bezel - Audio Effects on rotating bezel - Incredibly smooth movements - Professional and optimized coding to keep application size as small as possible - It's FREE
G	**The description of Compass** Do you always want to find a reliable partner to help you in determining the direction when you have business trip or traveling in the foreign countries? Compass For Android - Our compass application on mobile phone is that reliable partner. In all the designs of the screenshots, Compass Pro is a very special compass not only its high accuracy but also its extremely intelligent applications. Smart window with the large font on the Compass surface allows you to determine direction the fastest and the most exactly. And the biggest difference in Compass compared to other compasses is the application contains the perfect rotation. Currently, the application provides 8 rotations with a sharp decrease in resolution and over time it will be added more rotation at regular intervals. It is not only work as a regular compass, Compass is particularly suited to tech enthusiasts. This is evidenced by the superior features of Compass: - Easy to use as a true magnetic compass - Beautiful user interface with multiple Rotation & Needle HD Images - 100% App free - Display Direction by clear window - 8 different Dials and Needles Option - Very little equipment space required for installation - Large text display - Your current latitude and longitude in the most accurate display… How to use Compass is as simple as the way you use a conventional compass. Please hold the phone parallel to the surface of the earth but please check your device specifications before use and sure that your device have magnetic sensor because if it has a magnetic sensor, the Compass can work.
H	**The description of Accurate Compass** Accurate Compass App: Free Navigation Tool 2018 is best compass for android ever product of navigation. Have the compass 3D notification on android maps. Compass true north find shiny needle looks like a work of iron pro . Accurate compass pro tool as an android magnetic compass for pocket. Our orienteering compass helps you by pointing the magnetic north of earth. My compass app serve as a small compass of next gen. looking for hiking compass here it is as hiking free compass. The compass & elevation precise setting as real calibrated compass. Free compass app is the GPS compass for everyone. The amazing digital compass for old school style readers and navigators. Have the best geographic north pointing tool of planet. Accurate compass app for satellite dish help you to true north find for getting dish signal. Minimalist compass best digital compass for hiking. Most accurate magnetic declination correction for pointing magnetic north. You have to download variation device calibration accurate navigation tool. Are you looking for compass 3d here it is for every continent Australia, north America, Europe, Africa , Asia, south America even from Antarctica. Accurate Compass App: Free Navigation Tool 2018 is an international tool all around globe. Most of the direction problem is in metro politan cities of the world like London, Beijing, California, new York(NY), San Francisco, Chicago, Boston, Washington, Tokyo, Osaka, los angles, Hong Kong, Islamabad, Bombay, Delhi, Kolkata, Shanghai or any country where you are lost alone, here is the digital compass minimalist for you as navigation for driving.

	Accurate Compass App: Free Navigation Tool 2018 is ultimate tool. Ever best Komp app for the old school users for next gen digital world. Enjoy the best compass pro calibrated with compass sensor for android. Enjoy it as compass for galaxy. Ever best beveled navigation bar for user ease. Enjoy the free hiking compass as real navigator tool in any country America, Korea, Iran, Saudi Arab, Pakistan, china, turkey, England, Australia, Germany or any country where you do not know the way. The ultimate navigation compas app in you can say it is my compass. Declination of small compas for easy use of komp. Extreme calibrated with compass minimalist sensor. You can use it as compass Qibla. Enjoy the worldwide navigation compas tool. Digital compass for use of pocket compass in cell phone here it is. Accurate Compass App: Free Navigation Tool 2018 will serve you as professional compass for level error correction of mobile. Large iron simulation needles. Steel objects can influence the magnetic sensor of cell phone. In case of pointing in the wrong direction rotate the android phone. Pro shift the direction of mobile to get exact direction from location or pole finder. Get the flat earth compas for free to help yourself. How to use Accurate Compass App: Free Navigation Tool 2018 as pocket compas: - Download real compas for use - Open up app - The compas will show even on maps apps - Rotate mobile to activate magnetic sensor - Get the direction and navigation tool will help you to get there. - Use pocket compass and take a pro shift for directions. Features of Accurate Compass App: Free Navigation Tool 2018: - Very Simple to use - Use it like a real compas - Professional and easy to read design - The best compass card as flat earth compas - Swings naturally with magnetic north - Orientates like real kompass - You with just one glance will like it - A old school bearing provide detailed direction - Magnetic and true north is available - The app automatically takes care of variation - Incredibly smooth movements - No internet connection required. - It’s FREE
I	2017-05-13 A Simple and easy to use Offline Compass. Shows Precise GPS location (Co-ordinates and on Map) **** NEW FEATURES **** -> Maps with Compass View. -> Transparent Compass View. -> Screenshot and Sharing Option. -> *NEW* and Improved Interface. -> Fast and Accurate results. -> Compass View through Camera. -> Bugs Fixed.

J	To use this application, your device must have a compass sensor How to use: - Keep your phone parallel to the ground and turned toward the red arrow that you want to define - Compass will display on-screen directions and degrees. - It will also show your current location coordinates. *** Keep the device away from metal objects, machinery and where high magnetic field to avoid false results Applications compass, digital compass to help you determine the direction quickly and accurately. * Note: Your mobile device must have a compass sensor can use this application. N is north S is the South E is east W is the West NE is North-East SE is the Southeast SW is southwest NW is northwest. Vote and comment for App compass :)
K	👉 GPS compass for android takes advantage of compass & GPS & Network to get your position on Earth, and obtains map information near your location using Google Map and GPS locator and also provide the location of your friend.. My compass app is a tool to search bearings (azimuth, directions) using embedded magnetic sensors. 👉 When travel or lost your way then check your direction by GPS compass free. 🌊 GPS compass free has 6 significant features below. ✴ GPS compass for android is smart compass free and starts fast. Smart compass app is the best compass free, quite simply showing degrees and true north. Best compass permits you to line your directions by rotating the edge for easier and skilled navigation. ✴ GPS compass app is a digital compass free and and simply to use it sort of a real compass. You can find your way easily through the best compass app. A digital compass can be used for most of your outdoor activities such as travel, picnics, camping, hiking or boating. ✴ GPS compass takes advantage of compass and GPS and Network to get your position on Earth, and obtains map information near your location using Google Map and GPS locator and also provide the location of your friend. ✴ GPS compass allows user to find Restaurants, ATMS, Hotels, Bank, Schools, University, Post office, Cafe and Police station etc nearby. ✴ GPS navigation allows users to navigate destinations via directions and search maps using a number of different methods. Check the sensor and GPS & network is connected before you use this GPS tracking app. ✴ There are many compass app on market but most of them either work accurately when GPS is on or work accurately only in America but less accurate in Australia and Asia. My compass app can work accurately all over the world, as the compass app depends on the performance of your device exactly. If it is inaccurate, please check that you're being affected by a magnetic field. 🌊 How to use compass: ********** - Keep your phone parallel to ground. Smart compass app will show you direction and degrees. - GPS and google map are also included to find your route easily. - Flashlight on/off funtion is included. << Note >> To use GPS compass digital, hold your Android device flat, use just like a real compass. Your device must have magnetic sensor inside to read earth magnetic field. If your device does not have magnetic sensor compass app will not work. Please don't write bad comments, it's not our fault!

	Languages: ********** GPS compass for android supports the following languages: English, Spanish, Portuguese, Russian, Vietnamese, Indonesian, German and French ... Support: ********** If you have any problems installing or using the GPS compass application, please contact the team developed applications via mail e-mail: svmobileviet@gmail.com. We will contact you and solve the problem as soon as possible. If you like the app, please help me 5 star review. Thank you
L	1. Compass -- Shows device real-time orientation to magnetic fields. -- Ability to switch between true and magnetic North. 2. Location -- Address -- Location coordinates (longitude, latitude). -- Course. -- Speed. -- Altitude. -- Ability to switch between mph, feet units and kmh, meter units. 3. Weather -- Temperature information. -- Wind -- Humidity -- Visibility -- Sunrise,Sunset -- High/Low Temperature. -- Ability to switch between Celsius and Fahrenheit. 4. Map -- Standard, satellite, hybrid maps. -- Current location. -- Location tracking. 5. Gps signal indicator -- Gps accuracy indicator
M	Install "Accurate Compass" for your life. "Accurate Compass" is More Accurate ! More Useful ! "Accurate Compass" is available to choose several types of compasses such as Standard, Simple, Night Plus, Map Plus, etc., "Accurate Compass" can place some compasses on a Google map. When you run the compass on a map, you can see the direction of the map more accurately.

	"Accurate Compass" has a built-in level gauge so you can measure it more accurately. << Main Features >> - Several types of compasses can be freely selected. - Displays strength of the magnetic field. - Displays magnetic north and true north. - Displays latitude and longitude information. - Displays altitude information. - Displays a balance level. - Displays a compass on a Google map. "Accurate Compass" is a free app. Thanks. "Accurate Compass" is more accurate than other compass apps on most of smartphone. But, There is a inaccurate issues on some smartphones. We will solve this issue.
N	**The description of Simple Compass** A Compass can be used for most of your outdoor activities such as travel, picnics, camping, hiking or boating. There are many compass apps on the market but most of them work accurately only in America but less accurate in Australia and Asia. Our Compass apps can work accurately all over the world. Because of The compass app depends on the performance of your device exactly. If it is inaccurate, please check that you aren't being affected by a magnetic field. Your 5-star ratings will encourage us! Compass Features: ********** - Simple to use, use it like a real compass - Professional design - The dampened compass card, which swings naturally, orientates you with just one glance. - A decimal bearing provides detailed direction. - A cardinal bearing gives you a quick way of expressing general direction to others. - Magnetic and true north are available, the app automatically takes care of variation. - Incredibly smooth movements - No internet connection required. - Support many language - It’s FREE This is a simple but high precision digital compass. If you finding a minimal and beautiful compass, you will love this one. Don't lose your way and have a happy travel! The compass app depends on the performance of your device exactly. If the compass works perfectly, it means that your sensors are perfect, too. If it is inaccurate, please check that yours aren't being affected by a magnetic field. This app have several options to calibrate your device.

	Simple Compass is the most precise and performance optimized compass app available. It shows all cardinal points from the smallest to the biggest. This compass supports magnetic north and true north calculated using network or GPS location coordinates, which can be copied, shared and viewed in a map. This compass shows the magnetic field strength to check if there are interferences. The compass sensor precision is adjustable to save energy. Furthermore, this compass is optimized for all display sizes and resolutions. Download the best compass for free! When travel or lost your way then check your direction by Simple compass. Use this compass for select direction of your furniture and checking horizontal level. Calibration notification icon will help you keep compass in high accuracy. High-definition and simple graphic design makes high precision and battery efficiency. And compass's smooth and natural rotation is looks like real compass.
O	This software is the same class of Tactical navigation software. It can send to or receive location files from that software family. Military Compass Pro has many properties and will be developed in its own way. People or outdoor gamers can use it for location based tasks. Any other people who wants to mark their fishing points, water resources, any other important points can also use it. Military Compass Pro is designed for easy navigation. You can use it without internet connection but with internet more features are available. There are two location marker mode. First is like “I was here mode” and you can use it completely offline. Second mode need internet connection for location and routing planning but it is not need internet connection after planning phase, again you can navigate offline. Due to fact that locations can be exported and shared easily, you can use it outdoor group events, location based games or any outdoor organization. Property schema cab be seen here (http://mekanik.net/tactical-navigation-system-pro/) Features. - Analog Clock 24, Navigation Type Clock - GPS - Compass - Map - Military Navigation - Offline Navigation - Location Based Sun Phases (Rise, Noon, Set) - Magnetic Navigation Needle (Shows Target) - Distance Value to target in meters and feet - Accuracy - Current Location and Target Latitudes and Longitudes - Local Time and UTC Time - Day/Month/Day of Year/Week of Year - Backup and Load Locations - Export, Import and Share Your Locations - SMS Your Current Location to any person (via Latitude and Longitude pair or URL) - I was here mode Location Marker (No need to internet connection) - Pre-Location Marker for Route Planning - Manual Location insert available by Latitude and Longitude - Location Picking - Unlimited number of locations USAGE *I was here mode. (Enter by “Mark Here/Next” Button) **Mark Your Current Location: (I was here mode) Select “Mark Here/Next”>>>Select Name Area>>>Write Your Location Name>>>Press “OK” for Submit Your Location Name (This is important!) >>> Click “Mark Here”…….. That’s All… **Load Your Marked Location

	Select “Mark Here/Next”>>>Click “Load Target” Button. If you have marked your location before, You will see “Target Loaded Go to Main Screen” Alert. If you have no data, you will see “Empty Location Data, Mark First” Alert. Always verify your marking process by the way of Tip2. *Location Planner mode. (Enter by “Pre-Marker/Next” Button) Select “Pre-Marker/Next” Select Name Area>>>Write Your Location Name>>>Press “OK” for Submit Your Location Name (This is important!) >>> Select your Location on Map by tapping>>>Save Picked Location by Pressing “Save Picked” Button. ** Find and Save Any Location by Using Latitude and Longitude Data Select “Pre-Marker/Next” Select Name Area>>> Write Your Location by Using Latitude and Longitude Data into “Insert Latitude” and “Insert Longitude” boxes respectively. Data insert format is ex. 34.4567. >>> Click “Find Location Button” >>> Save Picked Location by Pressing “Save Picked” Button. ** SMS Your Location. >>> Use Blue “SMS” button. You can send your location many ways but here it is very easy way. You can edit your SMS message and receiver. Two different SMS options available. ** Backup and Load This options can be used for protecting your personal data against database corruption. You can use this buttons periodically. Remember “Load” button write your own backed up data on your existing one. ** Export and Import You can use this buttons similar reasons of usage of Load and Backup Buttons. But it is more than this. You can share all your data with your friends, and you can import your friend’s data. This is very useful for military games, military games, orienteering, sailing, fishing, trekking and similar.
P	With Easy Altimeter and Compass you will get an app that will make easy for you to know your location in a map, your altitude and your heading in a compass! Easy Altimeter has two methods of acquiring the altitude: direct GPS and Altitude Correction. Our algorithm will determine automatically which of the 2 methods is better and faster for determining your altitude based on current conditions. - Direct GPS altitude: Easy Altimeter will get the altitude direct from the feed of your GPS. This mode greatly depends on the quality of your GPS receiver and atmospheric conditions. Keep in mind that walls, vehicle roofs, tall buildings, mountains, and other obstructions may block line of sight to GPS satellites. - Altitude correction: Easy Altimeter calculates the earth surface altitude at your GPS position. Very reliable if you are at ground level. This calculation is slower that the direct GPS method and internet connection is required to perform the calculation. The map has also different modes: - Terrain: Displays a physical map based on terrain information. - Satellite: Displays Google Earth satellite images. - Map: Displays the default road map view.
Q	★ Tested by professional globetrotters ★ ★ For true adventurers ★ ★ You will never get lost ★ ★ Simple and reliable ★ ★ This simple, useful compass allows you to take the right course no matter where you are. Now the only thing you need is your own mobile phone! ★ Virtual compass is a navigation instrument which shows four cardinal directions. The application finds your actual position (using GPS) and determines all possible geographical directions. The aesthetic design of this sleek compass will not distract you from your priorities and will help globetrotters to make their way through many exciting adventures. ★ This smart compass shows not only North, South, East and West but also the azimuth and the angle. We recommend this

	user-friendly application for all those people who spend their spare time outside. Its professional look, magnetic and true heading, magnetic declination, measurement of angles, GPS coordinates and location will make using this application a pleasure. The application also contains a flashlight and map. So you can check your location and the route which you have taken. Take note! Not every model of smartphone has a magnetic field sensor. If your device does not have one, the application will not work. Sorry for this inconvenience. Contact us (mobile@netigen.pl) and we will try to help.
R	This is a simple golden compass, with high definition and high quality graphics. You can choose from 2 theme (Dark or Light). This compass can indicate True North (Default) or Magnetic North.
S	Compass & Bubble Level is the most easiest and professional tool. It can accurately display your current location, orientation and level in one screen. So that you grasp the moment to orient yourself, no longer lost your way now. Key Features: - orientation guide and point of view; - dynamic show the compass directions; - show your current latitude and longitude coordinates; - integrated compass, level and gps tools in one screen. - Quick to show your current GPS informations - Calibrate - Spirit Level (Clinometer) - Show angle or inclination - Orientation locking - Sound effects - Stylish design; Compass Bubble & Level is an indispensable tool for your daily life and outdoor activities. Tips: A bubble level is useful in construction, carpentry and photography, and it also helpful when you need to set up a tripod for photographs or hang paintings and other items on the wall.
T	Welcome to the Compass- Money Wise app! Listen and/or download your favorite Money Wise and Hey Howard programs. Check out our new whiteboard teaching videos, financial tools and share all kinds of information with friends via, Facebook, Twitter, email and more. For more information about Compass- finances God's way, visit us at www.compass1.org. The Compass - Money Wise App was created with the Subsplash App Platform. App: © 2017 Subsplash, Content: © 2017 Compass - finances God's way
U	This compass has 10 different center pieces (roses): * Degree and pointers * Big Letter * Old World

	* Air Plane * 360 Rose * Nordic * 3D Gold * Pirate Wooden * Gothic Pirate A settable degree dial, complete with ticking sound, which helps when you are trying to navigate your way back after that weekend of camping. A numeric and abbreviated heading readout. I hope you all have fun. If you have a case that has a magnetic strip(s) that helps hold your phone cover closed you will get bad results as long as your cover is over your phone or tablet. We have tested with and without the leather covers with the mag strips and the app behaves perfectly without the cover but has issues with them. For the best results hold the device at a 45 degree angle / (in between flat and straight up and down, this should give the best reading.)
V	An ad-free compass. No Permissions. - Displays the orientation of your phone in degrees. - Supports all screen orientations (phones + tablets). - Locking of orientation and reading of difference of angle Reported bugs will be fixed as soon as possible. Suggestions are welcome.
W	**Gyro Compass App for Android** Find the North direction with your mobile gyroscope sensor app. This is a high precision & insanely beautiful digital compass for android to find a direction of north & south when you are traveling in cities & countries. Don't lose your way & have a happy travel! Its 3d compass for Android - my smart compass app free for Android is an accurate compass to detect & navigate to the true north direction. Application compass is a digital compass altimeter to help you determine the directions, elevation, navigation, orientation, coordinates, current location quickly & accurately for the traveler, tourists, visitors, hikers for hiking, driving, boating & flying using your phone's magnetometer heading, bussola, البوصلة, compass rose. **How to use Compass for Android to True North Direction** > **To use this gyro compass app, your PHONE must have a COMPASS SENSOR OR GYRO SENSOR OR MAGNETOMETER SENSOR for your android phone** > Keep the device away from metal objects, machinery & where high magnetic field to avoid false results. > Keep your phone parallel to the ground & turned toward the red arrow that you want to define. > Android Compass will display on-screen directions & degrees. > You can try compass free app to find accurate results. > Navigator for driving: Navigate to your destination through way points, magnetic north. **IMPORTANT** > To use this application, your device must have a compass sensor for android phone. > The compass accuracy depends completely on the sensors on your device! If this compass points in the wrong direction, you need to calibrate your sensors. > If you encounter a magnetic north direction error, calibrate your phone by waving the device in figure 8, two or three times. > Do not use the Komp / Gyro Compass app with magnetic covers. Compass for Android: A Smart Compass App Free for Android is essential app for your Android phone and tablets. It is a professional compass in your pocket, when you need it, where you need it and you never know when it might come handy. Digital

	compass app shows direction of north, south, east and west, shows degrees in side window, has rotating bezel for advanced compass navigation. **Useful features of compass app for Android:** • Use free compass for navigation, map and address finding • True heading and magnetic heading for direction finder • Magnetic and true north are available, the app automatically takes care of variation • Magnetometer: display magnetic strength • Slope level meter • Kompass is simple to use, use it like a real compass • Professional vintage compass design of azimuth compas space needle • Large numbers and large rotating bezel • Use just like a real compass • Get directions with no voice navigation • Track your path with this kompas • Reach your destination accurately with speed & cover your distance in right direction • Qibla Compass: It can be used as qibla finder to find qibla direction A Compass can be used for most of your outdoor activities such as travel, picnics, camping, hiking or boating. There are many compass apps on the market but most of them work accurately only in America but less accurate in Australia and Asia. Our geo compass plus app can work accurately all over the world. **You must know about these signs:** N is north direction, My compass arrow can find it always S is the South direction, kompas tells it E is East direction W is the West direction NE is North-East direction SE is the Southeast direction SW is southwest direction NW is northwest direction Standard Compass Mode: This is your regular compass 360 that shows true north using Magnetic Sensor of samsung galaxy s6, s7, s8, s9, Qmobile, vivo, sony, oppo, motorola, nokia etc. The Compass on GPS Maps app is the most precise and useful app for navigation and orientation purpose that shows directions on Google Maps based on built-in magnetic sensor.
X	✿ The Accurate Compass app is like a real compass. It can be used for navigation, location and direction. The Compass app helps you find your way whether you are on a hiking trail or on a trip to a new location. The Compass app uses device' accelerator sensor and magnetic sensor to get magnetic north. If GPS or WiFi network is available, the compass app is able to get true north. The Compass marks your current position on Google Map and allow you to share your location to friends or family. ✿ The compass app can detect metal around you. A high level of interference from metal represented by high magnetic strength in red color or in yellow color leads to inaccuracy of the compass. You need to calibrate your phone by rotating in 8 figure direction. The normal magnetic strength in dark green color is around 49 micro-Tesla (uT). ✿ You can use the compass app to get current speed of your driving, biking, or boating. Speed unit is MPH or KPH. ✿ The compass app can route a trip, check traffic jam, and track your car movement. You search a destination place. Then the app draws a route from your current location to the destination location. You can turn on live traffic. So that you can choose the best road to go. While you are driving your car, the location of your car will update to reflect the car movement. ✿ You can view nearby places such as restaurants, ATMs, police stations, hospitals, gas stations, and cafe shops. By touching on

	mark of a nearby place, a route will be drawn from your current location to that nearby place. 🌸 Magnetic sensor is important for a compass to work. If this compass app does not work, please check the specifications of your device. The accurate compass can work without magnetic sensor but only while you are traveling. From setting of the app, you find a list of device models that support compass. 🌸 We would like to hear your feedback. Please write your comments on positives and drawbacks of the compass app. Features of the Accurate Compass app: 1. Accurate compass 2. Metal detection and magnetic strength 3. Sensors accuracy 4. Digital Clock 5. Background and text color customization 6. Current address & Google Map 7. Share current location 8. Keep screen on 9. Dim screen 10. Small file size 11. True north and magnetic north (the app automatically takes care of declination) 12. How to calibrate compass 13. Free forever compass app 14. Get more free apps (flashlight, digital clock, night mode, app lock) 15. Speedometer for car driving or biking 16. Route finder ** Note - The compass app uses new permissions model for high security. For a certain feature to work, you have to grant access right at run time and can revoke the right whenever you want from your device' setting. - The app requests Location, Network, and Draw over other apps permissions. The Location and Network permissions are required to get current location (using gps or network) of your devices and display it on google map. The draw on other apps permission is for dim screen to work. - The bottom of screen shows a small banner ads. This ad helps us keep and improve the app. Thank a lot for your understanding.

Table 1: Applications Index

ID	Name	App Size	Invoke Frequency	URL
1	Compass (No Ads)	1.9 MB	20239	https://apkpure.com/compass-no-ads/fr.avianey.compass
2	Classic Compass	3.5 MB	92	https://apkpure.com/classic-compass/com.eswn.compass
3	Compass Steel 3D	7.5 MB	26370	https://apkpure.com/compass-steel-3d/com.simplywerx.compass3d
4	Compass	3.7 MB	33450	https://apkpure.com/compass/com.gn.android.compass
5	Digital Compass	4.0 MB	33450	https://apkpure.com/digital-compass/com.vincentlee.compass
6	Compass	1.5 MB	18917	https://apkpure.com/compass/app.melon.icompass
7	Compass 360 Pro Free	5.0 MB	57593	https://apkpure.com/compass-360-pro-free/com.pro.app.compass
8	Compass	8.1 MB	72595	https://apkpure.com/compass/com.gamma.compass
9	Compass	1.4 MB	123	https://apkpure.com/compass/com.green.compass.star
10	Compass	1.8 MB	32693	https://apkpure.com/compass/com.zack.compass
11	Compass for Android	2.8 MB	31614	https://apkpure.com/compass-for-android-app-free/tntstudio.supercompass
12	Compass Free	4.1 MB	72588	https://apkpure.com/compass-free/com.compassfree
13	Compass	4.2 MB	52466	https://apkpure.com/compass/com.fulminesoftware.compass
14	Compass Steel (No Ads)	8.0 MB	22204	https://apkpure.com/compass-steel-no-ads/com.simplywerx.compass2d
15	GPS Compass Navigator	2.5 MB	47434	https://apkpure.com/gps-compass-navigator/com.evo.gpscompassnavigator
16	Compass	7.3 MB	25876	https://apkpure.com/compass/com.devuni.compass
17	Compass with declination	2.3 MB	56363	https://apkpure.com/compass-with-declination/com.Kidshandprint.sunpositionbycompass
18	Compass	1.7 MB	26352	https://apkpure.com/compass/apps.r.compass
19	Compass For Android	8.4 MB	49134	https://apkpure.com/compass-for-android/lulu.drmundo
20	Compass Level & GPS	4.9 MB	58482	https://apkpure.com/compass-level-gps/com.jee.level
21	Simplest Compass	0.0168 MB	38	https://apkpure.com/simplest-compass/com.nextw3.simplestcompass
22	Color Compass	3.5 MB	80300	https://apkpure.com/color-compass/s.d.f.compass
23	Compass	1.6 MB	29667	https://apkpure.com/compass/com.asciifalse.dev.compass
24	LED Compass	2.0 MB	18664	https://apkpure.com/led-compass/com.basicapp.gl_compass
25	Positional Easy GPS & Compass	1.8 MB	28630	https://apkpure.com/positional-easy-gps-compass/io.trewartha.positional
26	Compass	9.4 MB	65499	https://apkpure.com/compass/espengineer.android.compass.free
27	Compass GPS	1.4 MB	24884	https://apkpure.com/compass-gps-free/com.GZ.compass
28	Compass	3.4 MB	41201	https://apkpure.com/compass/org.nixgame.compass
29	Compass	6.0 MB	75353	https://apkpure.com/compass/com.unght.compass
30	Accurate Compass	2.6 MB	41035	https://apkpure.com/accurate-compass/com.andymstone.accuratecompass
31	Simple Compass	5.0 MB	90554	https://apkpure.com/simple-compass/co.kr.generic.simplecompass
32	Aircraft Compass Free	0.5815 MB	3874	https://apkpure.com/aircraft-compass-free/com.sensorworks.aircraftcompass_free
33	Digital Field Compass	1.0 MB	9953	https://apkpure.com/digital-field-compass/com.chartcross.fieldcompass
34	GPS Compass Explorer	5.3 MB	45047	https://apkpure.com/gps-compass-explorer/com.gpsnav.evo.gps2
35	compass 2018	1.4 MB	24892	https://apkpure.com/compass-2018/com.ZA.compass
36	Maps - Compass GPS Navigation & Route Finder App	31.1 MB	26443	https://apkpure.com/maps-compass-gps-navigation-route-finder-app/com.ezi.gps.compass.freeapp
37	Compass(True North)	4.4 MB	36407	https://apkpure.com/compass-true-north/com.q9tech.tool.compass

38	Qibla Compass - Prayer Times, Azan & Ramadan 2018	13.4 MB	95314	https://apkpure.com/qibla-compass-prayer-times -azan-ramadan-2018/com.qiblafinder.prayertime. hijricalendar
39	JS Compass	3.6 MB	51534	https://apkpure.com/js-compass/com.crazylabs. aswin.jscompass
40	_ No Ads Compass _	4.2 MB	75456	https://apkpure.com/%F0%9F%8C%8D-no-ads- compass-%F0%9F%8C%8D/com.ctzone.compass
41	3D Stabilized Ball Compass	2.7 MB	21219	https://apkpure.com/3d-stabilized-ball-compass/ com.kettler.free.gp.ballcompass3d
42	Compass PRO	5.0 MB	72593	https://apkpure.com/compass-pro/com.compasspro
43	Accurate Compass	5.8 MB	46141	https://apkpure.com/accurate-compass/com. appcamp.lifecompass
44	Simple Compass	1.4 MB	13347	https://apkpure.com/simple-compass/krasivei. apps.simplecompass
45	Military Compass Pro	15.4 MB	19953	https://apkpure.com/military-compass-pro/aa.mcpro
46	Easy Altimeter and Compass	3.1 MB	52292	https://apkpure.com/easy-altimeter-and-compass /com.chopitas.altimeter
47	Best Compass	7.6 MB	75173	https://apkpure.com/best-compass/pl.netigen.compass
48	Compass	4.2 MB	8077	https://apkpure.com/compass/com.pinux. compass
49	Compass - Bubble Level	1.3 MB	13364	https://apkpure.com/compass-bubble-level/ com.eliferun.compass
50	Compass - Money Wise	7.9 MB	47911	https://apkpure.com/compass-money-wise/ com.fcbh.dbp.s_GT98SM
51	Compass	3.1 MB	25056	https://apkpure.com/compass/com.cliftonrfarrisllc. compass
52	AdFree Compass	0.4268 MB	115	https://apkpure.com/adfree-compass/de.uvwxy. compass
53	Gyro Compass App for Android: True North Direction	24.1 MB	33832	https://apkpure.com/gyro-compass-app-for-android -true-north-direction/com.baz.gyro.compass.free.app
54	Compass	2.4 MB	33358	https://apkpure.com/compass/com.myapps.dara.compass
55	Minimal Compass	0.351 MB	4875	https://apkpure.com/minimal-compass/com.roshan.compass
56	Speaking Compass	0.0749 MB	50	https://apkpure.com/speaking-compass/com.talking.compass
57	Compass Plus	7.3 MB	8138	https://apkpure.com/compass-plus/com.pinux.compassplus
58	Compass	7.7 MB	84839	https://apkpure.com/compass/com.compass.livewallpaper
59	Smart Compass digital	4.1 MB	27647	https://apkpure.com/smart-compass-digital/smart. boussole.compass
60	Compass	1.6 MB	15135	https://apkpure.com/compass/com.carrotapps.compass
61	Feng Shui Compass	5.8 MB	61105	https://apkpure.com/feng-shui-compass/com. thaidang.battrach_phongthuy
62	Accurate Compass	6.7 MB	28190	https://apkpure.com/accurate-compass/com. dungelin.compass
63	Marine Compass	1.8 MB	1798	https://apkpure.com/marine-compass/net. pierrox.mcompass
64	Compass Free	20.4 MB	45202	https://apkpure.com/compass-free/com. test.Compass
65	Simple Compass	4.2 MB	54860	https://apkpure.com/simple-compass/com. goodtool.five.compass
66	Compass For Android	5.5 MB	92768	https://apkpure.com/compass-for-android/com. compass.pro.start
67	Accurate Compass on Google Map -Compass Navigation	6.2 MB	72426	https://apkpure.com/accurate-compass-on-google- map-compass-navigation/com.accurate.compass. directionfinder.map
68	AR GPS Compass Map 3D	2.4 MB	29385	https://apkpure.com/ar-gps-compass-map-3d/ com.kettler.argpsc3d
69	Geo Compass	3.4 MB	54958	https://apkpure.com/geo-compass/net.mainvision. geocompass
70	Compass	0.3139 MB	21	https://apkpure.com/compass/com.twodlevel. compass

71	Compass For Direction	1.8 MB	29070	https://apkpure.com/compass-for-direction/com.zoom.compass
72	Compass (Offline)	6.1 MB	86751	https://apkpure.com/compass-offline/com.hindsoftwares.compassoffline.compassoffline
73	Schneider Compass	3.1 MB	46815	https://apkpure.com/schneider-compass/com.schneider.compass
74	3D Compass and Magnetometer	2.9 MB	15573	https://apkpure.com/3d-compass-and-magnetometer/com.plaincode.magnetmeter
75	Digital Compass	10.6 MB	9390	https://apkpure.com/digital-compass/com.anjan.compass
76	CM Flashlight (Compass, SOS)	1.8 MB	36379	https://apkpure.com/cm-flashlight-compass-sos/com.cmcm.flashlight
77	Compass and GPS	1.3 MB	27937	https://apkpure.com/compass-and-gps/cps.mmxi.smartcompass2
78	Compass 2018 Navigation & Directions	5.5 MB	52680	https://apkpure.com/compass-2018-navigation-directions/com.compass.travel.directions
79	TrueCompass Digital Compass	8.1 MB	104393	https://apkpure.com/truecompass-digital-compass/tap.truecompass
80	Compass - Maps & Directions	8.9 MB	78318	https://apkpure.com/compass-maps-directions/com.jvstudios.compass_mapnavigation
81	Compass	4.6 MB	88582	https://apkpure.com/compass/comsol.com.compass
82	Compass Real	3.5 MB	22882	https://apkpure.com/compass-real/co.kr.sonky.sonkycomapss
83	Vastu Compass	0.1077 MB	1115	https://apkpure.com/vastu-compass/com.vastunidesh
84	Compass & Satellite Navigation	7.2 MB	51539	https://apkpure.com/compass-satellite-navigation/com.discipleskies.android.compass
85	Tamil Compass	1.4 MB	7358	https://apkpure.com/tamil-compass/androapps2015.tamil.compass
86	Powerful Compass	4.8 MB	63328	https://apkpure.com/powerful-compass/com.forte.usefultool.compass
87	Vastu Compass	45.6 MB	22249	https://apkpure.com/vastu-compass/au.com.itango.vastucompass
88	GPS Compass	6.1 MB	85837	https://apkpure.com/gps-compass/com.quangdz.gpscompass
89	Material Compass	1.4 MB	18512	https://apkpure.com/material-compass/net.marlove.compass
90	Flashlight Compass with Sounds	8.7 MB	97864	https://apkpure.com/flashlight-compass-with-sounds/com.mobusi.flashlightcompass
91	Compass Calibration Tool	2.0 MB	34486	https://apkpure.com/compass-calibration-tool/com.appire.compasscalibration
92	Smart Compass	4.4 MB	31355	https://apkpure.com/smart-compass/com.rotate.compass.direction.free
93	Compass - with camera view	2.4 MB	38859	https://apkpure.com/compass-with-camera-view/crunchybytebox.cameracompass
94	Compass for android	4.5 MB	36356	https://apkpure.com/compass-for-android/com.compass.good.vtel
95	3D Compass Plus	3.1 MB	51148	https://apkpure.com/3d-compass-plus/com.a0soft.gphone.aCompassPlus
96	Compass GPS	6.1 MB	90770	https://apkpure.com/compass-gps/com.raxes.compass
97	Feng Shui Compass	3.6 MB	22605	https://apkpure.com/feng-shui-compass/com.falcon.fengshuicompass
98	Compass Free	5.1 MB	33014	https://apkpure.com/compass-free/com.free.app.compass
99	Compass Camera (Compocam)	4.0 MB	17375	https://apkpure.com/compass-camera-compocam/com.procop.mtools.compass
100	Digital Compass	2.1 MB	33912	https://apkpure.com/digital-compass/com.vscomputing.digitalcompass

Bibliography

Bibliography

[1] Shahid Alam, Zhengyang Qu, Ryan Riley, Yan Chen, and Vaibhav Rastogi, *Droidnative: Semantic-based detection of android native code malware*, 2016.

[2] Bela Amro, *Malware detection techniques for mobile devices*, 2018.

[3] Android, *Codenames, tags, and build numbers.*

[4] ———, *Dalvik bytecode.*

[5] ———, *Dangerous permissions.*

[6] ———, *Dangerous permissions table.*

[7] ———, *Deprecated.*

[8] ———, *Environment sensors.*

[9] ———, *Identifying sensors and sensor capabilities.*

[10] ———, *Motion sensors.*

[11] ———, *Normal permissions.*

[12] ———, *Permissions overview.*

[13] ———, *Position sensors.*

[14] ———, *Sensor availability.*

[15] ———, *Sensors overview.*

[16] ———, *Signature permissions.*

[17] ———, *Special permissions.*

[18] ———, *What is api level?.*

[19] Abhishek Vasisht Bhaskar, *Automated code extraction from packed android applications*, Ph.D. Thesis, 2016.

[20] Thurston HY Dang, Petros Maniatis, and David Wagner, *Oscar: A practical page-permissions-based scheme for thwarting dangling pointers*, 26th USENIX security symposium (USENIX security 17), 2017, pp. 815–832.

[21] Michael L. Dertouzos and Michael L. Dertrouzos, *What will be: How the new world of information will change our lives*, 1st ed., HarperCollins Publishers, 1998.

[22] Anthony Desnos et al., *Androguard*, 2011.

[23] Adrienne Porter Felt, Erika Chin, Steve Hanna, Dawn Song, and David Wagner, *Android permissions demystified*, Proceedings of the 18th acm conference on computer and communications security, 2011, pp. 627–638.

[24] Wolfram Language and System Documentation Center, *Partitioning data into clusters.*

[25] Enrico Mariconti, Lucky Onwuzurike, Panagiotis Andriotis, Emiliano De Cristofaro, Gordon Ross, and Gianluca Stringhini, *Mamadroid: Detecting android malware by building markov chains of behavioral models*, 2016.

[26] Wolfram Mathematica, *Wolfram mathematica modern technical computing.*

[27] Microsoft, *Understanding android api levels.*

[28] Mila Dalla Preda, Mihai Christodorescu, Somesh Jha, and Saumya Debray, *A semantics-based approach to malware detection*, Vol. 42, ACM, 2007.

[29] Suzanna Schmeelk, Junfeng Yang, and Alfred Aho, *Android malware static analysis techniques*, Proceedings of the 10th annual cyber and information security research conference, 2015, pp. 5.

[30] Penn State University, *Smartphone application analysis.*

[31] Analytics Vidhya, *An introduction to clustering and different methods of clustering.*

[32] Rossouw Von Solms and Johan Van Niekerk, *From information security to cyber security*, Vol. 38, Elsevier, 2013.