University of Hradec Králové
Faculty of Informatics and Management
Department of Information Technologies

MASTER'S THESIS

Radio Fingerprint Acquisition Using Smartwatch

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Study programme: Applied Informatics

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Prohlášení

Prohlašuji, že jsem diplomovou práci vypracoval samostatně a uvedl jsem všechny použité prameny a literaturu.

Declaration

I declare that I have elaborated this thesis independently and listed all the sources and literature.

Hradec Králové day 26th of April 2018 Bc. David Sucharda

Poděkování

Rád bych zde poděkoval Ing. Pavlu Kříži, Ph.D. za odborné vedení práce, podnětné rady a čas, který mi věnoval.

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I would like to thank to Ing. Pavel Kříž, Ph.D. for professional guidance, incentive advices, and the time he gave me.

Anotace

Název práce: Sběr rádiových fingerprintů pomocí chytrých hodinek

Diplomová práce se zabývá možnostmi sběru rádiových otisků (fingerprintů) za pomoci chytrých hodinek. Tyto otisky se používají k lokalizaci uvnitř budovy. Hlavním cílem této práce je prozkoumat možnosti sběru otisků a návrh aplikace která bude tento sběr umožňovat. V první části práce je potřeba zjistit, jestli je tento sběr na hodinkách vůbec možný. V další části je zpracování aplikace na mobil a hodinky. A jako poslední část této práce je sběr otisků a jejich analýza. Jeden z osobních cílů je zpracovat tuto aplikaci aby byla co nejvíce uživatelky přívětivá.

Annotation

The Master's thesis deals with possibilities of collecting radio fingerprints with the help of smart watches. These prints are used in indoor localization. Main aim of this thesis is to explore possibilities of fingerprint collection and creation of application that will allow it. First part is to figure out if this collection is even possible using smart watch. Next part deals with creation of such application not only for watch but also for the phone. And at the end part there is testing of fingerprint collection and data analysis. One of the personal goal is to make this application as user friendly as possible.

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1 Introduction

As the technology evolves it unlocks more and more possibilities. Just few years back there were no smart watches or phones but at this time they are important part of our lives. As they evolve there is the need for them to have more functions and features. One of them is to locate it's position on the map. This information is very useful since it can prevent people from getting lost, figuring out path to drive, used by military and countless more cases.

Finding out such position is possible using Global Navigation Satellite System (GNSS). Multiple implementations of this system exist like GPS, GLONASS or Galileo. All of these systems provide location using sufficient number (at least four) of satellites.[1][2] GNSS solution requires clear path between satellites and the receiving device because signal is not able to pass through buildings. That makes it the main reason why it cannot be used for indoor localization.

There are multiple approaches to find out location inside the building. They can be divided into three main types. First type is using wireless signal ranging approach with multiple kinds of data like Time of Arrival (ToA). Second approach is using special equipment like active bats (Ultrasonic). And final type based on Signal Strength Fingerprint Maps (SSFM), in which first part is to collect signal strengths from the environment and construct fingerprint maps. They are then used to match with current signal to obtain the location.[3]

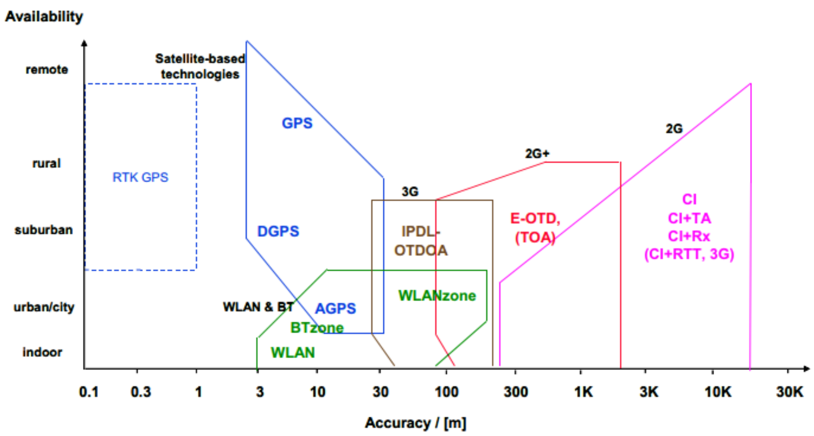

Figure 1.1: Comparison of Positioning Technologies (source: [4])

In addition to these types there are also multiple algorithms used in indoor localization. Some of them are location fingerprinting, triangulation, proximity and dead reckoning.[5] Description of few algorithms can be found in chapter 2.

This thesis is focused on method using radio signal strength (RSS) fingerprinting collecting data from bluetooth, wireless and cellular networks.

1.1 Goals of this thesis

Main goal of this thesis is to explore possibilities of fingerprint collection using smart watch technology. The first question that needs to be answered is if this can be done. Is smart watch capable of RSS data collection? And the answer to this question is yes since smart watches have the similar specifications as low-end smart phones.

One of the goals for this thesis is to create an application for Android phone and wear device which handles fingerprint collection. Problem with smart watches is their diversity in operational system because a lot of watch creators build their own custom systems which can complicate things. Luckily there is new system from Android called Wear 2.0 and it is basically port of Android system to wearable devices.

And final goal is to test created application and figure out if it's data are useful for indoor localization or not.

1.2 Reason for selection of this topic

The reason behind selection of this topic is rather simple. I was introduced to Android during my studies at the University but it was not any deep knowledge so I decided to go for a study abroad to deepen my knowledge. Part of that study was to work for a company where we developed rather technical heavy Android application. It's core part was using multiple APIs but it was focused only on a singe device. So next thing I wanted try was working with multiple kinds of devices and since Android Wear 2.0 is rather new I wanted to test it out. So the main reason is to get more experienced with Android and as a developer.

2 Localization techniques

This chapter describes most common techniques and methods for localization. Most of these approaches have multiple implementations and can be also used in parallel. Fingerprinting for example can be used to increase accuracy of other methods.

2.1 Triangulation

Methods based on Triangulation use geometric properties of triangles to determine target position. This can further be divided into Lateration and Angulation. [6] There are multiple sources of data these methods can use like distance estimation between device and specific transmitters, measurements of the signal propagation-time (TOA: Time Of Arrival and TDOA: Time Difference of Arrival[7]) and the direction of received signal (AOA: Angle of Arrival[8]).[9]

2.1.1 Lateration

Lateration refers to the technique of determining position based on distance measurements that are calculated using specific devices that know their own position. Mainly used types of Lateration and are Trilateration and Multilateration.

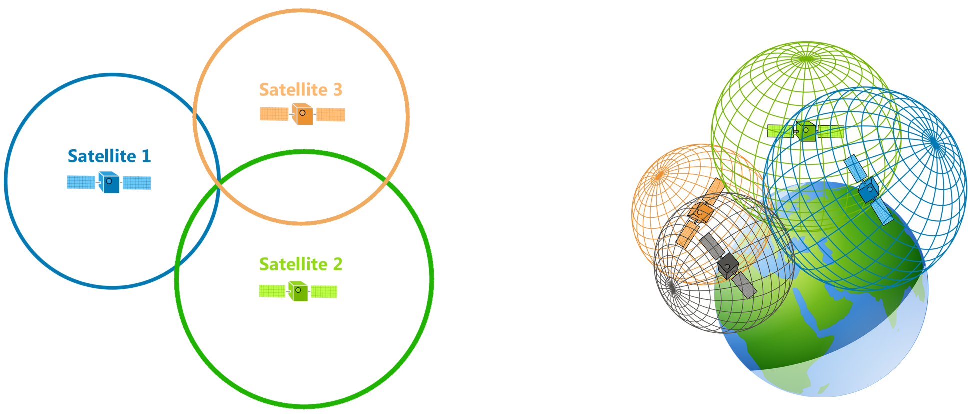

Figure 2.1: 2D and 3D Trilateration (source: [10])

Trilateration uses distance measurements from at least three devices in particular as "tri" in the name suggests.[6] Figure 2.1 illustrates usage of Trilateration in 2D and 3D environment. While working in 2D plane will result with only one specific location point. Moving to the 3D plane can create a problem because signal is send in a sphere which could result in more than one position. That is the reason why some systems use at least four signal sources, example of such system is GPS.[2] Advantage is easy implementation and simple calculations. One down side of this approach is that all devices must have synchronized clock.[6]

Multilateration also known as hyperbolic positioning is using Time Difference of Arrival (TDoA) instead of Time Of Arrival (ToA) used in previous case. This approach involves the intersections of hyperbolas rather than circles as shown in Figure 2.2. Main advantage of this method is that only receiving devices must have synchronized clock instead of all.[12] Multilateration was developed for tracking aircraft position and it is widely used.

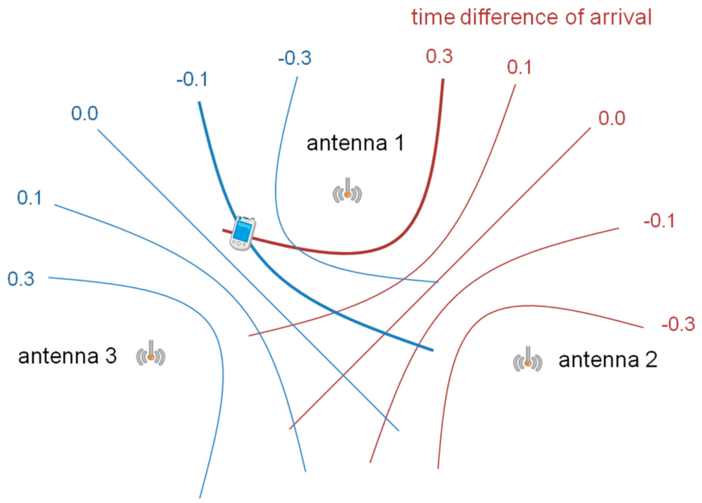

Figure 2.2: Multilateration (source: [11])

Note: At this time term Multilateration is not as strict as it used to be. It can now refer Lateration with more than three devices.

2.1.2 Angulation

This technique uses Angle of Arrival (AoA) of radio signals to determine location. It uses highly directional antennas or antenna arrays. Same as Lateration these antennas are placed in known location and basic AoA requires at least two of them to determine position on 2D plane but more of them can be used to improve accuracy.[6] That makes it an advantage over Trilateration. Second advantage of this approach is no need for synchronization between devices.

There are few disadvantages of this approach since it needs complex hardware setup due to the use of antennas. Other problem is with multipath locations since it can cause signal reflection making it not useful for indoor localization. And final one to mention is the decrease of accuracy when mobile target moves further from the antennas.[13][14]

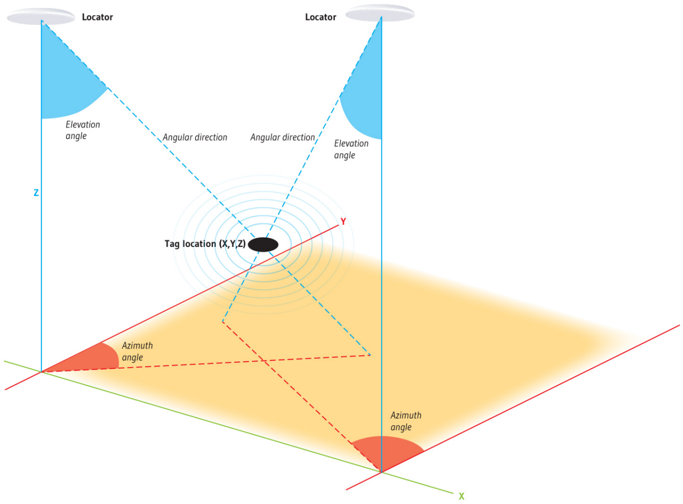

Figure 2.3: 3D location using AoA from Quuppa Intelligent Locating System (source: [15])

2.2 Fingerprinting

This method is a part of Signal Strength Fingerprint Maps (SSFM) type. Main point of this approach is using previously recorded data to figure out device location. Hence fingerprint term in the name. There is multiple kinds of radio signal sources like bluetooth, wireless or cellular devices that can be recorded.

Fingerprinting has two main phases where the first one is fingerprint maps construction also called offline phase. They are created by collecting Received Signal Strength (RSS) and optional extra features in known locations. All these values are saved in the database and it is called fingerprint map. The second phase is localization itself also known as online phase where the device measures RSS values and compares them with fingerprint maps to approximate position using suitable method. [3][16] Most used algorithms or methods to approximate position are [9]

- probabilistic methods,
- k-Nearest Neighbors,
- neural networks,

- support vector machine,
- smallest M-vertex polygon.

There are multiple advantages of this approach and the most important is that it does not need any additional or specialized hardware. Next one is no need for time synchronization between the stations. Both of these advantages make it simple and cost effective method for localization. On the other hand building of the map is very time consuming and needs heavy calibration. It is also susceptible to changes in environment like people presence, object movement or relative humidity.[9][17]

2.3 Proximity

Proximity detection also known as connectivity based positioning calculates only approximate location. Position is determined by cell of origin (CoO) method with known position and limited range.[6] Specific device location is based on cell of the connected device ("associated access point" in Wi-Fi 802.11 systems) as shown in Figure 2.4.[18]

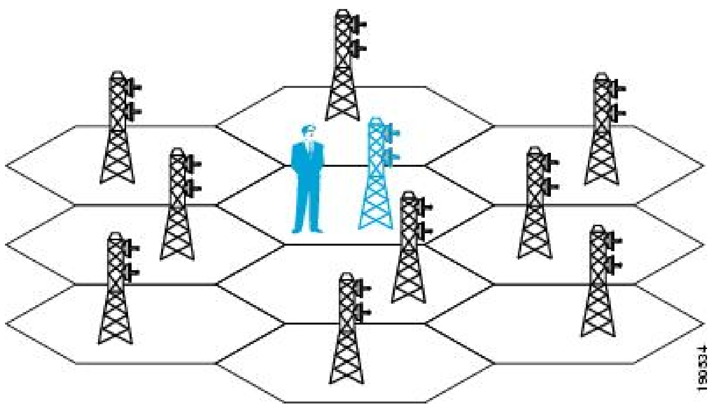

Figure 2.4: Cell of Origin (source: [18])

Primary advantage of this approach is very easy implementation and no need for complicated algorithms and thus making calculations fast. However, for various reasons devices can be associated to cells that are not in close physical proximity. Such errors can happen for example in multi-floor buildings where floor cells overlap. There are additional methods that can be used to improve localization such as using received signal strength indication (RSSI), manual method (human search) or connecting to device with highest signal strength.[18][6]

2.4 Other techniques

Scene analysis is a pattern recognition method that uses features of a scene observed from a particular vantage point to draw conclusions about the location of the observer or of objects in the scene also.[19] This approach has been used in many applications, such as image and speech recognition, as well as location.[20] The advantage is that the location of objects can be inferred using passive observation and features. The disadvantage is that the observer needs to have access to the features of environment against which it will compare its observed scenes.[19]

Dead Reckoning refers to a position solution that is obtained by measuring or deducing displacements from a known starting point in accordance with motion of the user.[21] Basically calculate new position based on starting point, travel distance and angle of movement. Because new position calculations are dependent on previous ones there is the need for high accuracy of data since it makes errors cumulative.[22]

3 Android

This chapter will provide information about Android and Wear 2.0 technology. Why it was developed and what are the differences between previous version and other wear technologies.

Android is a Linux based operating system for mobile and wear devices developed by Google. The main selling point of this system is that it's open-source project, meaning that everyone can access the code and modify it as they wish. Android was mainly developer for mobile phones but since that time it moved beyond that by being implemented to all kinds of wear devices, tablets, televisions and even refrigerators or cameras.[23]

3.1 Android system structure

Android is created as a stack, meaning there are functional modules stack on top of each other from Linux core over native libraries to applications as shown in Figure 3.1. Android maintains complete software stacks to enable device creators to run and modify Android for their specific hardware. To support these modifications and testing every release has multiple "code lines" to separate stable versions from experimental work.[24]

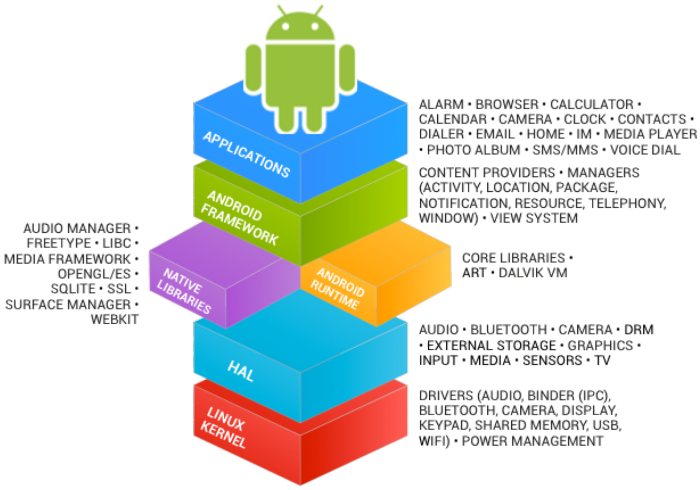

Figure 3.1: Android stack (source: [24])

There are multiple versions of Android system at this time and every single one has it's own version, code name and API level. Version codes are number identifications of a specific system version. Highest levels of these numbers are grouped into code names that are ordered alphabetically. As an example versions 8.0.0 and 8.1.0 have the same code name called Oreo. Finally API level is number identification for compatibility of specific application and it will be compared to API level of device Android system.[24][25]

3.2 Wear technologies

Interactive wearable, as an example smart watches, is a new part of mobile computers. Wear devices are categorically different from phones or tables in term of usage, design and user interfaces (UI). According to the app design guidelines by major vendors, users interact with wearable devices frequently throughout daily use. Each interaction is short, often less than 10 seconds, and is dedicated to simple tasks.[26]

3.2.1 Android Wear 2.0

3.3 Other wear technologies

4 Analysis, design and implementation

This chapter describes all important information about created application. One of the main parts are hardware and software used for developing and testing of the application. Other part is structure and description of core parts used in the application.

4.1 Hardware

4.1.1 Smart Watch

4.2 Software

4.2.1 Android

Android Wear

4.2.2 AltBeacon Library

4.2.3 SQLite database

4.2.4 Couchbase database

4.2.5 TileView

4.3 Application structure

4.3.1 Mobile application

Activities

Model

Utilities

4.3.2 Wear application

5 Testing and data analysis

This chapter goal is to show application testing, data collection and analysis.

5.1 Data collection

5.2 Analysis

6 Conclusion

6.1 Application improvements

Literature

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