Multimedia Vehicular Smartphone Docking with GPS Tracking

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Abstract

The Internet of Things (IoT) connecting many electronic devices via internet has been ubiquitous in the last decade. For instance, electric or hybrid cars and autonomous vehicles which are supported by many automotive and IT companies. IoT does not only provide internal monitoring service of the devices, but also the environmental situation. Meanwhile, smartphones are equipped with embedded built-in sensors, and also providing wireless communications. In consequence, vehicular telematics based on smartphone is growing rapidly. This paper proposes a vehicular smartphone docking prototype. It aims not only to provide an affordable alternative to Android Auto and CarPlay, but also to complement them, particularly in vision and security cases. The main issue is that the driver should not be distracted while driving. Such distraction may cause road accident which can lead to severe injuries and even death. Therefore, it is important to design a vehicle smartphone docking to guarantee distraction avoidance and to provide multimedia and localization services. This vehicular smartphone docking architecture consists of an Android smartphone and a Raspberry Pi. Several test drives were conducted with perfect results. Based on the experiment results, this system is able to reduce the number of modules required within a smart vehicle.

Keywords: Vehicle telematics, smartphone, multimedia services, GPS tracking

1. Introduction

The Internet of Things (IoT) has been ubiquitous in the last decade. In short, IoT connects electronic devices via Internet [1], for instance: household appliances such as microwave, washing machine, electric stove, and refrigerator; health-care equipment such as wireless blood glucose monitor, stethoscope, and heart rate monitor. Other prominent examples are electric or hybrid cars and autonomous vehicles which increasingly popular since they are supported by many automotive and IT companies, such as Tesla [2], Audi [3], Toyota [4], Honda [5], and Nvidia [6].

IoT provides monitoring service of both the devices and their environment. The connected devices are able to acquire status alerts, then they may take actions necessary to respond according to the status alert. Moreover, IoT regularly generates a vast amount of data. Those data may be utilized for optimizing device performance, behavior, and environmental analysis. For instance, a parking space classification designed using image

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features and machine learning [7], a ball detection algorithm for humanoid soccer robotic using Android smartphone [8], decision tree analysis for multi-sensor fusion in humanoid robot soccer goalkeeper [9], and traffic sign detection with optimized frame rate processing [10]. In the next decade, the number of connected devices is predicted to be over 10 billion or has been increasing over 200% since 2016 [11].

Smartphone is not only equipped with many embedded built-in sensors, but also providing wireless communications and social interaction. Using smartphone to collect data and utilizing its telecommunication channel to transmit information acquired by sensors is named telematics [12], such as autonomous vehicle or smart buildings. In fact, vehicular telematics based on smartphone is growing faster than vehicle-fixed sensors [13]. The reasons are obvious: the vast number of smartphone market and user, scalability, and affordability. Moreover, smartphone does not only provide quick audio and visual notifications for user, but also supports telematics services and social networks integration [14].

There are two main disadvantages in using smartphone for supporting vehicular telematics [13]. First, sensors embedded within smartphone have relatively lower performance compared to fixed sensors. In consequence, several statistical noise analysis may be employed to compensate such shortcomings. Second, the battery drain issue. More applications installed within smartphone and larger data communication capability means more energy consumed. Since the smartphone does not require specific vehicle to work with, the driver can employ this system even if he or she drive another vehicle.

There are two profound examples of smartphone-based vehicle telematics developed in the last decade. In 2006, a sensing computer system named CarTel was designed to collect and analyze data [15]. Then in 2008, the mobile millennium project, a collaboration of University of California, Berkeley and Nokia, provided a large-scale traffic data collection using smartphone [16]. Other popular features for a vehicular smartphone integration are multimedia support or leisure activities within vehicle, vehicle environmental security, and vision for autonomous vehicle. It is desirable to build an efficient and easy-to-use vehicular smartphone apparatus since it should be installed smoothly into various kinds of vehicular type and model.

This paper discusses a prototype of a vehicular smartphone docking. It aims not only to provide an affordable alternative than Android Auto [17] and CarPlay [18], but also to complement them, particularly in vision and security cases since both products have not included security features for the driver [19]. For instance, the driver should not be distracted while driving. The distraction may include drowsiness, fatigue, telephone or video call, music or video streaming, and textual or instant messages. Those distraction may cause road accident which can lead to severe injuries, damage, and even death. Therefore, it is important to design a vehicle smartphone docking which includes not only those distraction avoidances, but also provide multimedia and localization services within vehicle.

This article begins with introduction and background problems explained in section 1. The system architecture, using two major modules composed of Raspberry Pi and Android smartphone, is explained in Section 2. The experiments conducted, results, and analysis are described in Section 3. At last, Section 4 concludes the result.

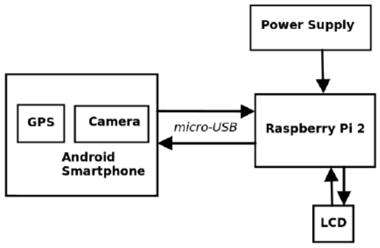


Figure 1. The vehicular smartphone docking architecture

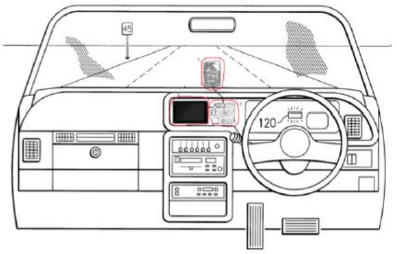


Figure 2. The vehicular smartphone docking installed on the car dashboard [21]

2. System Architecture

The vehicular smartphone docking architecture, as illustrated in Figure 1, consists of two main aspects, i.e., an Android smartphone as the master and a Raspberry Pi module as the slave. The smartphone records vehicle travel video, acquires vehicle location, direction, and the average speed based on GPS [20]. Those data are stored temporarily in the smartphone's external storage, and then be fed into Raspberry Pi storage using a micro-USB cable. The vehicular smartphone docking installation at the car dashboard is displayed in Figure 2.

2.1. Vision & Location Services: Android

The Android smartphone handles several aspects used in the vehicle smartphone docking which are described as follows:

1) GPS Localization: In Indonesia, there are small number of vehicle with Global Positioning System (GPS) integrated. In consequence, people have to install a GPS module whenever they need localization services. Nowadays, most people that own a car have their own smartphone too. In addition, GPS has been included in a quite large number of Android smartphone version. GPS enables user to locate vehicle in a map, avoid dense traffic, and provide alternative paths.

   By using a GPS in the smartphone, an user is able to record vehicle traveling history. Moreover, the proposed smartphone docking also stores vehicle's average speed, direction, and GPS accuracy. The Android utilizes `getSpeed()` and `getAccuracy()` methods to measure vehicle speed in km/h, and GPS accuracy in meters (m), respectively. Meanwhile, orientation sensor generates smartphone's direction. However, the GPS reception depends on area condition which is related to satellite accessibility. In general, GPS used in big cities provide more accurate and details compared to small cities. Hence, a large GPS margin error percentage is still acceptable.

2) Mapping: Android provides Google Map facility to aid user in finding road routing to destination. It is user friendly since the map provides vehicle's current position automatically via either GPS, WiFi, cellular positioning system, or a combination of them. Then to display the location, pin within map is used. This pin is able to move according to the vehicle current location.

3) Black Box: Vehicle traveling video can be used to expose situation near the vehicle itself. Smartphone's camera records front view of the vehicle, and the resulting video is stored within smartphone's temporary (external) storage before being moved into Raspberry Pi's memory. This original video format, without any data compression, may increase the memory usage quickly. In consequence,

there are four additional image processing and communication coding methods utilized to lower the memory usage. These methods are employed during the video recording preparation and described as follows:

- Bit rate encoding (BRE). Android provides `setVideoEncodingBitRate(int bitRate)` method to set video bit rate encoding recorded by smartphone's camera.
- Frame per second (FPS). Android provides `setVideoFrameRate(int rate)` method to set video's FPS.
- Video resolution. Android provides `setVideoSize(int width, int height)` method to set video resolution width and height.
- Video compression. Android provides `setVideoEncoder(Media.Recorder.VideoEncoder.H264)` method to select a video encoder, including the compression algorithm.

In general, there are two main classes of compression method, i.e. lossy and lossless compression [22]. The lossy compression method generates slightly different decompressed data compared to the original data to be compressed. However, this method is sufficient to be used in limited conditions. JPEG, MPEG, and H.264 are examples of the lossy compression method [23]. Meanwhile, the lossless compression generates exactly the same decompressed data with the original data to be compressed. LZ77, Huffman code, arithmetic coding, DMC, and RAR are examples of the lossless compression method [23].

Currently, H.264 is one of the best video encoding method, in terms of compression size and quality, compared to other methods available. The newer format, H.265, is still under development when this research is conducted. H.264 or MPEG-4 part 10, or called advanced video coding (AVC), is a video compression with ISO and ITU standards and often used to record, compress, and distribute high resolution videos [22]. It enables computing performance of such system. The H.264 video encoder block diagram is presented in [24]. Then, the overall video recording procedure is presented in Figure 3.

After an hour, the smartphone stops to record video, store it in temporary memory and then start it over again for a new video file until the user stops it manually. Then, these video files are transferred to Raspberry Pi storage to be encoded using H.264. Hence, it is necessary to check whether the available storage in smartphone is greater than 2 GB or not.

2.2. Storage & Controller: Raspberry Pi

As the slave in the system, a Raspberry Pi 2 (13) has specifications as follows:

- 900MHz quad-core ARM Cortex-A7 CPU
- 1 GB RAM
- 4 USB ports
- 40 general purpose input/output pins
- 3.5 mm audio jack
- 1 SD card slot

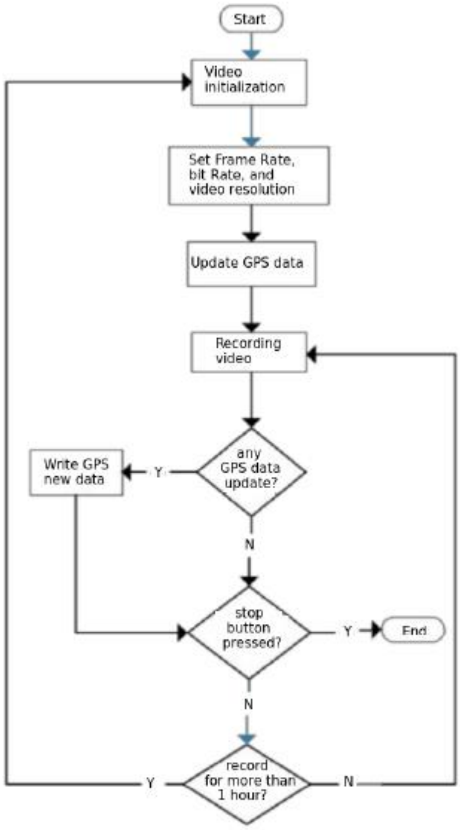


Figure 3. The video recording procedure

Users has flexibility to locate their smartphone as far as the micro-USB cable length. While connecting to Raspberry Pi module, user is required to open the smartphone vehicle docking application. In addition, there is an LCD display for Raspberry Pi to enhance multimedia user experience. Data communication from Raspberry Pi to the smartphone is established using serial scheme, then Raspberry Pi is able to recognize multimedia file in the smartphone storage.

The Raspberry Pi module supports multimedia services by providing music and video players. These players are able to run multimedia files stored in the Raspberry Pi. By looking at the LCD screen, a user might easily chooses music file, watches video, controls volume, and plays music or video files, either randomly or in sequence.

3. Experiment, Result, and Discussion

3.1. Smartphone Application

An ASUS Zenfone 5 smartphone served as the master, and was used for smartphone application testing purpose by developing a simple GPS tracking application. This smartphone has specifications as follows:

- Intel Atom Multicore Processor Z2520
- 8 GB internal memory and 2 GB RAM
- Android OS, version 4.4.3 (KitKat)
- 8 MP main camera and 2 MP secondary camera
- 2110 mAh battery capacity

- 148.2 × 72.8 × 5.5–10.3 mm dimension and 145 g weight

The Android GPS tracking application user interface was designed as simple as possible, as shown in Figure 4.

Latitude : -7.32020944036173
Longtitude : 110.49436304313753
Negara :Indonesia
Nama Jalan : Jalan Imam Bonjol
Kota/Kabupaten :Salatiga City
Kelurahan : Sidorejo Lor
Kecamatan : Sidorejo
Arah Kompas: 113.0
Kecepatan :14.98047981262207 Km/s
Keakuratan : 24.0 m

Figure 4. The Android GPS application

3.2. Experiment Result and Discussion

When connecting smartphone to Raspberry Pi, it took 3 to 4 minutes to mount Raspberry Pi manually in an Android smartphone. To resolve this problem, user still had to press a confirmation button to transfer video recording files from smartphone to Raspberry Pi. During the 15 minutes of video recording, it took approximately 5 minutes to transfer a 164 MB video to Raspberry Pi. The complete 15 minutes of video testing results are displayed in Table 1.

Table 1. The results of 15 minutes, 640 × 480 (VGA), 15 fps, video recording

No	BRE	Original Size (MB)	Compressed Size (MB)	Compression Rate (%)	Video Quality
1	550k	150	65	43.3	Fair
2	850k	206	83	40.3	Good
3	1M	264	107	40.5	Good
4	1.3M	303	140	46.2	Good
5	1.5M	337	161	47.8	Good

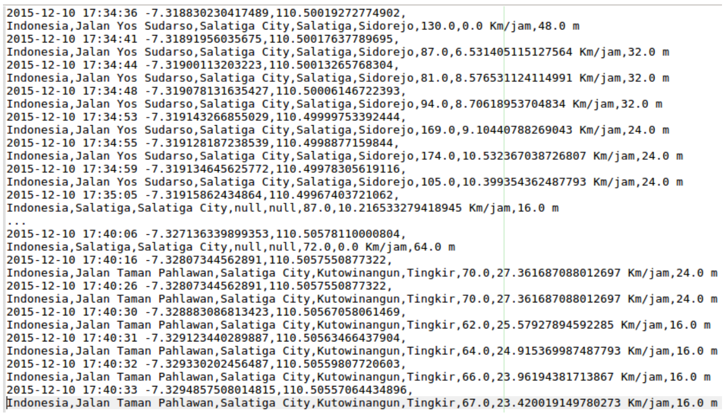
From Table 1, it can be seen that generally the bigger BRE then the higher compression ratio achieved, for good quality videos only. It means that for the longer videos, the H.264 compression rate would perform better than the short ones. However, there were some limitations in the experiments, e.g. memory storage maximum capability and availability, and time to travel around the city. By using Raspberry Pi, a user was able to play music or video files from a directory. Besides he or she was able to stop, pause and resume multimedia files using available buttons in the user interface. When tested using Raspberry Pi LCD, the video display was not so clear, because the frame rate was only 20 fps.

The complete system experiment was conducted in both days and nights condition. Unfortunately, smartphone camera would produce better and clearer videos in days rather than nights, since there was limited light source in nights. A screen-shot of a test driving around Salatiga city at around 5:30 pm is shown in Figure 5. The video recording and GPS data reception were conducted perfectly. Also, whenever there was an incoming call, the system was able to send a text message to the caller. Unfortunately, video recording was stopped after sending the message because incoming calls have higher priority than video recording. Moreover, to record a video, the smartphone display has to be linked with video preview. So, the system was unable to continue video recording, either manually or automatically, since user interface was not responsive. User was able to select video specifications, e.g., BRE method, frame rate, and resolution. This setting would be stored and could be restored anytime using interface shared preference in the smartphone.

Figure 5. The smartphone vehicle docking afternoon testing

The videos taken from the vehicle smartphone docking camera have to comply with Undang-Undang (UU) No. 19, 2002, chapter 19 verse 1 about intellectual rights [25]. It stated that these videos cannot be duplicated and distributed without permission from people captured in the videos. In consequence, the videos may be used for personal use only. The violations of the UU may be sanctioned as stated in chapter 72 verse 5. However, the videos can be used as legal law evidences, whenever used in law enforcement, as stated in UU No. 11, 2008, chapter 5 verse 1 [26].

The GPS tracking log format is: *date-time, latitude-longitude, location, direction (in range 0-359), speed (km/h), and accuracy (m)*. Those data were updated whenever there was a movement, or in different location. The log format of GPS tracking is displayed in Figure 6. There were several null information, where GPS could not receive any data. This was caused by the GPS was unable to retrieve road information.



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2015-12-10 17:34:36 -7.318830230417489,110.50019272774902,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,130.0,0.0 Km/jam,48.0 m
2015-12-10 17:34:41 -7.31891956035675,110.50017637789695,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,87.0,6.531405115127564 Km/jam,32.0 m
2015-12-10 17:34:44 -7.31900113203223,110.50013265768304,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,81.0,8.576531124114991 Km/jam,32.0 m
2015-12-10 17:34:48 -7.319078131635427,110.50006146722393,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,94.0,8.70618953704834 Km/jam,32.0 m
2015-12-10 17:34:53 -7.319143266855029,110.49999753392444,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,169.0,9.10440788269043 Km/jam,24.0 m
2015-12-10 17:34:55 -7.319128187238539,110.4998877159844,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,174.0,10.532367038726807 Km/jam,24.0 m
2015-12-10 17:34:59 -7.319134645625772,110.49978305619116,
Indonesia,Jalan Yos Sudarso,Salatiga City,Salatiga,Sidorejo,105.0,10.399354362487793 Km/jam,24.0 m
2015-12-10 17:35:05 -7.31915862434864,110.49967403721062,
Indonesia,Salatiga,Salatiga City,null,null,87.0,10.216533279418945 Km/jam,16.0 m
...
2015-12-10 17:40:06 -7.327136339899353,110.50578110000804,
Indonesia,Salatiga,Salatiga City,null,null,72.0,0.0 Km/jam,64.0 m
2015-12-10 17:40:16 -7.32807344562891,110.5057550877322,
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2015-12-10 17:40:26 -7.32807344562891,110.5057550877322,
Indonesia,Jalan Taman Pahlawan,Salatiga City,Kutowinangun,Tingkir,70.0,27.361687088012697 Km/jam,24.0 m
2015-12-10 17:40:30 -7.328883086813423,110.50567058061469,
Indonesia,Jalan Taman Pahlawan,Salatiga City,Kutowinangun,Tingkir,62.0,25.57927894592285 Km/jam,16.0 m
2015-12-10 17:40:31 -7.329123440289887,110.50563466437904,
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2015-12-10 17:40:32 -7.329330202456487,110.50559807720603,
Indonesia,Jalan Taman Pahlawan,Salatiga City,Kutowinangun,Tingkir,66.0,23.96194381713867 Km/jam,16.0 m
2015-12-10 17:40:33 -7.3294857508014815,110.50557064434896,
Indonesia,Jalan Taman Pahlawan,Salatiga City,Kutowinangun,Tingkir,67.0,23.420019149780273 Km/jam,16.0 m
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Figure 6. The result of GPS tracking

Based on the log, it can be inferred that the GPS accuracy is between 16–24 m. It is quite large margin of error in localization service, compared to the WiFi localization which employed 3 access points and could achieve at most 5 m location prediction error in a smaller scale experiment compared to this research [27]. The vehicle direction receives data from an orientation sensor installed within smartphone.

The power supply specification required for the Raspberry Pi is 5 V / 2 A to ensure the Raspberry Pi and LCD modules cold work well. The relatively small battery capacity of the smartphone decreases its efficiency. To overcome this shortcoming, smartphone always connects to Raspberry Pi module. Hence, smartphone battery was continuously charged. For caution, this was not a good practice to charge continuously while using GPS and multimedia service, since it might cause battery leakage. It is supposed to have a circuit breaker to stop overcharging.

While driving, the driver has to fully concentrate to vehicle surrounding situation, particularly the front view vision since the vehicle are moving forward most of the time. Using telephone while driving is a serious violation of UU No. 22, 2009, chapter 106 verse 1 [28]. It stated that the driver has to drive the vehicle with full of concentration. Whenever there is a phone call, then it will close it automatically. In addition, the smartphone will send a text message to the caller, which explains that the smartphone owner is currently driving a vehicle. Hence, it is necessary to have remaining credit balance. Whenever there is not enough credit balance, it may use other communication media such as WiFi, bluetooth, or radio as in a push-to-talk application, with their own limitations.

4. Conclusion

This multimedia vehicle smartphone docking is able to work well in several constraints, e.g. a small video resolution and large video files size. Hence, these limitation can be resolved using a smartphone with better camera and memory size than the ones used in testing condition. However, the highlight of this system is its ability to reduce the number of modules required in typical multimedia, tracking, and smartphone capabilities within a vehicle. In consequence, the cost of having such a diverse systems could be decreased. Another main advantage of using this system is that the driver may keep his focus while driving the vehicle. Whenever there is an incoming or voice call, the caller is able to get a notification that the smartphone's owner or holder is currently driving.

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