Review and Design of GPS-RFID Localization for Autonomous Vehicle Navigation

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ABSTRACT
This paper discusses an alternative solution to the problem of autonomous vehicle navigation systems on the choice of technology in positioning the vehicle at a low cost but carries a high level of risk. The idea of using sonar and GPS in the navigation system can be an option, but the use of sonar is constrained by crosstalk problems between one sonar sensor and other sonar sensors. The use of Light Detection and Ranging (LIDARs) is also constrained by the high costs and stereo vision in LIDARs requiring powerful specific hardware to process camera information. Research studies on navigation systems using GPS-RFID based localization for visually impaired people become an inspiration for the idea of developing autonomous vehicle navigation using RFID-GPS fusion technology. The idea frame is to install RFID tags on the roadside that contain information on the location of routes to be taken by autonomous vehicles, reading RFID tags by Reader RFID with combined GPS module reading data will result in a more accurate location and is believed to be a reference for autonomous vehicle navigation systems. The initial results of several research studies on RFID testing for localization combined with GPS modules indicate that this idea is feasible.

CCs Concept
Hardware→Communication hardware, interfaces and storage → Sensors and actuators

Keywords
GPS; RFID; Navigation; Autonomous Vehicle; Localization.

1. INTRODUCTION
Electric Vehicles technology is growing rapidly and attractively to continue to be studied and researched because Electric Vehicles technology potentially to be developed compared with fossil vehicles technology. Transportation technology with fossil fuels contributes to the occurrence of acute air pollution. One of the biggest contributors to air pollution is gas emissions from fossil fuel vehicle, transportation technology with fossil fuels is the cause of the greenhouse effect and various diseases such as cancer, so that an effective solution that can reduce environmental problems is among others developing electric vehicles [1]. Research on autonomous vehicles is part of research on electric vehicle technology that is widely studied today, this technology allows vehicles to operate effectively safely and independently without being controlled by humans. This autonomous vehicle is a collection of systems that are integrated and synergistic to allow the vehicle to drive and trace the road route in an area. Sensor devices are the most important element in the development of autonomous vehicles [2]. Research on the use of sensor devices in navigation systems is usually associated with expensive costs [3], so some studies have developed navigation systems and obstacle avoidance systems using GPS and sonar. GPS-sonar fusion can be used to determine the position and avoid obstacles, commands given in the navigation algorithm are translated in the movement and detection of obstacles by vehicles navigating adjusting the direction points set on the GPS and detected by sonar [4]. Even though it is relatively low-cost, the use of sonar sensors has a problem with the crosstalk between one sonar sensor and another sonar sensor [4]. The use of LIDAR sensors requires special hardware to process camera information at high prices [3].

There are two systems for autonomous vehicles [5] :

- Internal Vehicle Systems: Sensor of Wheel Speed, Sensor of Yaw Speed, Sensor of Lateral and Longitudinal, Steering Input, Driver Input, Hydraulic pump/Hydraulic brake booster, Transmission Output, Powertrain output, and HMI.
- External Sensing Systems: ultrasonic sensor, RADAR, GPS, LIDAR, cameras, Vehicle to Infrastructure (V2I), Vehicle to vehicle communication (V2V), and FUSION.

Location detection is the substantial process in the Navigation, localization is provided through the combination of GPS, lasers, odometry, the several fusions from the latest mix. however, some

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technologies are not able to provide accurate and high-cost localization as well as fusion carried out by LIDAR [3] [6]. In this paper, a system is designed to be a solution to localization problems, where a combination of Global Positioning System (GPS) and Radio Frequency Identification (RFID) is a combination of technologies that are often used in developing wireless tracking systems to send and receive location data both outdoor and indoor [7].

2. RELATED WORK

2.1 Navigation on Autonomous Vehicles

The navigation system of an autonomous vehicle is part of External Sensing because this system serves to provide information about the position and route that refers to the vehicle while moving. Autonomous vehicle navigation generally applies GPS modules along with other integrated sensor devices such as LIDAR, RADAR, sonar, camera or ultrasonic sensor. In the navigation system, these sensor devices are needed with reactive and planned features so that autonomous vehicles can run on real roads with changing conditions and routes. In developing intelligent system software for unmanned vehicles, it is very important to use biological systems as the main consideration, especially biological function systems in humans. An intelligent system needs to combine capabilities such as sensing, reasoning, action, learning, and collaboration [8]. Autonomous vehicles have a working principle that is almost the same as humans when walking, to determine which route must be passed by the senses in this sense of sight, when humans have limitations on the senses, humans need direction in tracing the path to be passed. Humans with visual impairment problems in some cases use sticks to guide and direct them to find road routes. This traditional method is passive because humans have to find a route using signs that they understand. When they do not succeed in finding the right sign some problems will definitely be a barrier, some people with visual impairments use guide dogs as an option to guide them along the road [9]. Automation in autonomous vehicles must also consider the factors of safety and security of passengers in it, automation is eliminating the role of humans from the system which means eliminating the risk of human error which is then taken over by systems [10] and an autonomous vehicle must be fulfilled these criteria.

2.2 GPS-RFID Localization

The use of several sensors that are fused by several sensor devices to produce data that is processed as a reference to the navigation system seems to have become a necessity, it is seen in several publications relating to navigation and localization of positions. the Fusion method often never leaves the use of GPS (Global Positioning System) [3] [9] [11] [12] [13] [14].

The high performance of Global Positioning System (GPS) receiver system with real-time kinematics provides absolute localization for driverless vehicles. However, the method has a vulnerability to multipath effects is also not effective and optimal on Error-Correction Performance in navigation, so this method is used to obtain accurate global positioning system-inertial measurement unit (GPS-IMU)/Dead Reckoning (DR) data fusion method measurement based on a limited set of prediction models and grid models [11]. The weakness of this system because of the need for complex modeling and complex formulations and an impact on measurement accuracy.

Strictly combining GPS pseudorange and Doppler measurements with other sensors is a method to improve the accuracy and integrity of positioning information especially when it is calculated autonomously [12]. Video cameras are used to obtain relative information by observing the lane markings and dead-reckoning sensors as well as being integrated to provide information on positions with high availability. The experimental results show that this tightly coupled approach clearly improves performance in terms of accuracy and integration compared to loosely coupled methods that use GPS repairs calculated by external receivers [12]. This method provides better accuracy and reliability. This system provides a very cost-effective solution for the task of localizing autonomous vehicles but the disadvantage of this method is the risk of errors in reading the road if the lighting required is not as expected.

High accuracy is very necessary for the navigation system and the provision of high accuracy is difficult to fulfill in conventional localization systems using GPS modules, so that the localization system using RFID technology can be a solution to the problem. Hae Don Chon and friends use RFID technology in navigation systems to improve accuracy [15]. Simulation shows that, using RFID assisted localization systems, vehicles can obtain accurate positions both on the highway and in urban areas [16]. Identification technology using RFID is an identification technology that allows tracking of objects and humans. information captured is location data or identity data, the method used to obtain this data is localization of RFID tags embedded in other devices or objects including humans. The advantages of this technology are due to low power consumption, light weight, and simple and unlimited capacity identification capabilities. Radio frequency identification (RFID) has been widely recognized for its advantages, it can be seen from the promising potential in context-aware computing, where the method of reading RFID tags by RFID Reader, information about the environment at a certain time or character of an entity can be obtained, besides that RFID technology has been proven to be able to overcome problems in terms of financing, accuracy [17] and saving energy [18].

3. PROPOSED SYSTEM

3.1 Block Diagram System

The picture below shows a Block Diagram of the navigation system on autonomous vehicles proposed in this paper.

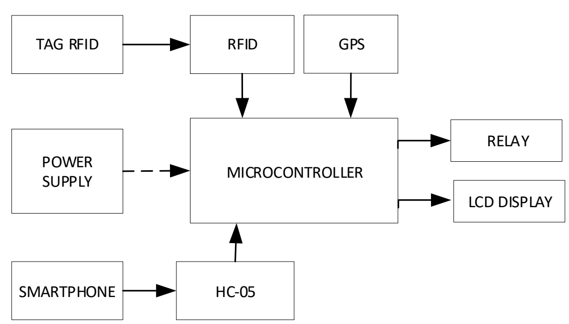

Figure 1. Block diagram of navigation system.

The GPS-RFID Localization System Block Diagram is shown in Figure 1, from the figure it can be explained the process of the proposed autonomous vehicle navigation system.

- RFID Module, consisting of RFID Readers and RFID Tags
- GPS module, serves to determine the location of the vehicle

- Bluetooth modules are used for Communication Controllers and Smartphone Devices for Data Interfaces
- Main controller, for processing all inputs and all modules/devices connected in the system
- Output module, in the form of a relay connected to a particular device, is used as input trigger and also display module

3.2 The Frame of Navigation System

The principle of an autonomous vehicle navigation system is inspired by research on navigation systems for visually Impaired people who use navigation systems using GPS-RFID based localization [9] [19]. RFID technology enables automatic non-contact identification, with advantages in the form of large capacity capability, long service life, long reading distance, and allows identification of Gadgets that cannot be compared with other identification technologies [19]. In the guidance system of the blind, there are difficulties and obstacles in guiding the journey of the blind. The blind navigation system is RFID-based, combined with cellular communication, in addition to having a large coverage of this low-cost system. Blind people can walk, find roads, ride buses, and search for specific locations with a system consisting of RFID readers (can be integrated into sticks), antennas, RFID tags, cellular terminals, call centers, route servers and existing information database tags [19]. The concept of utilizing RFID and GPS for navigation is technically and economically feasible because after the existence of an efficient RFID and GPS localization algorithm, it has reduced the barriers to the development of this technology [9].

RFID communication is the process by which an RFID reader transmits waves to an RFID tag and then receives back data from an RFID tag and to get the data it takes at least one communication between the reader and the RFID tag in the reading area. RFID readers are installed on vehicles that travel at a certain speed, so the reading area will also move for a particular period of time. Eun-Kyu Lee defines RFID read latency as a time period when one communication occurs and an RFID reader manages to get data from an RFID Tag installed [20].

Table 1. Movement speed table in the RFID reading area

Speed [km/h]	**Computed** [sec]	**Measured** [sec]
10	0.665	0.360
20	0.332	0.180
30	0.222	0.120
40	0.166	0.090
50	0.133	0.072
60	0.111	0.060
70	0.095	0.051
80	0.083	0.045
90	0.074	0.040
100	0.067	0.036

In a previous study on Installation and Evaluation of RFID Readers on Moving Vehicles, the read latency is upper-bounded by vehicle speed when driving. In table 1, there is a test result that shows the gap between the value of 'computed' and the 'measured' value caused by the reduced length of the reading area of RFID in actual conditions [20]. The table shows that read latency must be less than 36 ms at a speed of 100 km/h [16].

- In his research, Ghiotto designed a Passive UHF RFID antenna to operate at 915 MHz with EM4222 passive RFID chip installed on conventional SOT23 packaging [21] [22], EM4222 is a chip used in passive read-only UHF transponder applications, It is powered up by an RF beam transmitted by the reader, received and improved to produce supply voltages for chips [23], these chips are capable of transmitting 64 bit data at 256 kbps [13] [20] [21] [23], which means it is needed 0.22ms for sending 64-bit tag data [20], Eun-Kyu Lee Test shows that the average read latency is 38.89 ms, this slow communication is mainly generated from the time lag on the selected tag with a maximum value of 62,5 ms. This means that the possibility of RFID communication cannot occur when vehicles travel at speeds exceeding 60 km/h, because the speed of moving from the reading area becomes 60ms or becomes shorter [20].
- Readings of RFID tags on a 500 m track with 250 RFID tags installed in each 2 m showed that only 125 tags were read when the vehicle was running, or only 50% of the RFID tags were read. In other words, the level of RFID readings will decrease because of the faster vehicle speed factor, as explained earlier that the velocity of the reading area (36ms at 100km / hour) is faster than the average read latency measured (38.89ms). This means that RFID reliability is reduced because the RFID Reader skips one RFID tag without RFID communication. To overcome this problem, the average read latency is shortened to less than 36 ms at 100 km / h or by extending the reading area by reducing the speed of the vehicle [20].

The following figure presents a description of the Navigation System that describes the proposed GPS-RFID Localization System Framework.

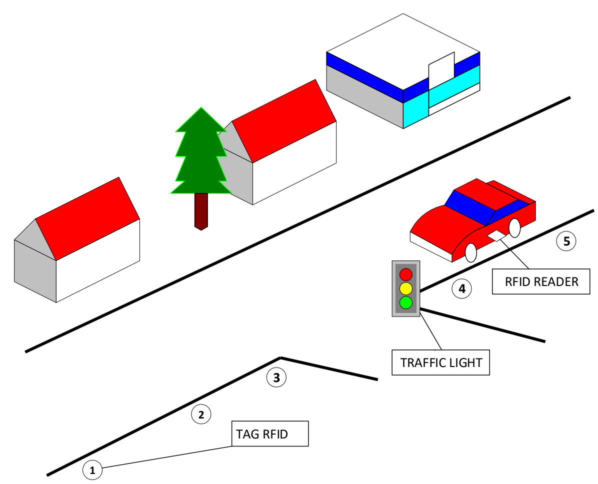

Figure 2. The navigation system framework.

From Figure 2, it can be explained the Framework for GPS-RFID Localization Systems for Autonomous Vehicle Navigation, with the following rules:

- RFID Reader installed on Autonomous Vehicles that drove on the road.
- The RFID tags installed on the roadside with the specified height, so that the RFID Reader can detect the RFID tag.

- Each installed RFID Tag (1-5 etc.) stores location information and road coordinates
- Specific RFID tags (number 4) installed near Traffic Light, when autonomous vehicles read RFID tags, the red lights on the traffic light are on, allowing autonomous vehicles to drive on the track safely.
- Data Readings of RFID Tags by RFID Reader and Coordinate Position of Vehicles by GPS Modules used for navigating autonomous Vehicles.
- Navigation algorithms are designed by using location data parameters from RFID tag reading [24] and vehicle position from reading the GPS Module [25], which will regulate autonomous vehicle navigation in driving on a predetermined route.
- RFID tags installed on the roadside have functions as infrastructure entities that will be pass through by autonomous vehicles, such as bus stops, intersections and other entities. [16] [19].

RFID devices used in autonomous vehicles are RFID types with UHF frequencies, taking into account the range of relatively far distances and fast transmission times [16] [20]. Installing this RFID device can be added to the antenna to increase the accuracy of RFID readings [16].

The following Flowchart image describes the stages of navigation using the GPS-RFID Localization System.

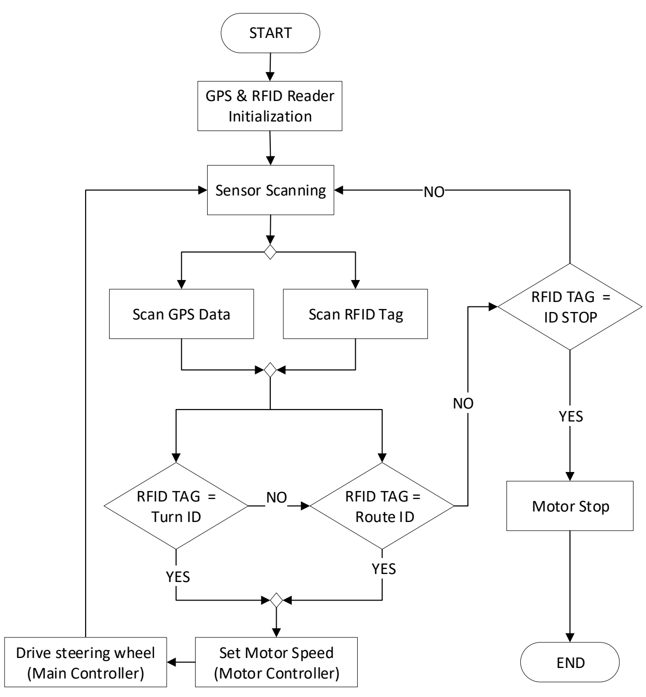

Figure 3. Flowchart of navigation system.

Figure 3. shows the workings of the RFID Reader and GPS that read RFID tag location data with the coordinates of the position as a sign of a road route that will be passed by autonomous vehicles. The navigation algorithm will calculate and process all parameters to be able to control the steering of the vehicle and adjust the motor speed that represents the navigation of autonomous vehicles [25] [24].

Finally, this paper explained previous research on localization systems using RFID on Vehicular Ad hoc Network (VANET) technology. This technology is used to monitor public transportation flows and detect emergency situations that occur along the route [16]. The test results show that RFID readers cannot communicate with RFID tags installed at the curb when a vehicle is moving at speeds exceeding 60 km/h [13]. The Novelty from the proposed research design is the implementation of the GPS-RFID localization method for autonomous vehicle navigation. Based on previous research experiments, communication is possible between RFID Reader installed on an autonomous vehicle with RFID tags installed on the roadside. This RFID tag functions as a marker when an autonomous vehicle going straight or turning in the direction. In other words, the RFID tag installed along the route becomes a guide for moving autonomous vehicles.

4. CONCLUSION

From the previous discussion in this paper, it can be concluded that the Autonomous Vehicle Navigation System is can be implemented. By combining RFID Reader reading data on RFID tags installed on the roadside and GPS data readings in the form of vehicle position data coordinates, with navigation algorithms the data is processed into information the route and location that the vehicle passes through using the GPS-RFID Localization methods.

Reliability of the navigation system built using GPS-RFID Localization method for Autonomous Vehicle Navigation can be shown from the experimental results and testing in the form of GPS performance data and RFID modules. This is an implementation of work that can be done in the future, in the form of experiments using navigation algorithms using GPS-RFID localization and testing. GPS accuracy in determining predetermined location points and RFID identification on RFID transponders installed at roadside when the vehicle is moving fast.

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