Budapest University of Technology and Economics
Faculty of Civil Engineering
Department of Photogrammetry and Geoinformatics

Possibilities of the use of the radio frequency identification

Supporting positioning and transportation by radio frequency identification technology

PhD Thesis

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1. Introduction

The object of my research is the various application of the radio frequency identification (RFID) system which is capable of immediate information transmission and identification in a non-line of sight mode. Radio frequency identification is a radio-based communication technique that provides an opportunity to develop engineering applications. The main motivation of my research is to increase the road safety and efficiency with the use of the radio frequency identification system as traffic accidents are the leading causes of death. The emphasis is laid in my work on the prediction and detection of the vehicles moving in opposite direction because this type of accidents has typically serious or fatal outcome due to high speed differences.

During the research, various measurements with the available RFID system have been executed; indoor and outdoor propagation circumstances, the regularities and correlations between signal strength and distances have been analyzed, as well as the detection options in various traffic situations at different speeds and layouts to determine the reading success rate. The validity of the use of the radio frequency identification as indoor location and navigation system has also been examined.

2. The objectives of the research

The Department of Photogrammetry and Geoinformatics of BME also participated in the Safespot project, which was funded by the European Union Framework 6 Program. My work in this project provides the relevant outdoor part of my doctoral research. For outdoor applications, the main area of interest is how to increase traffic safety, since traffic accidents often cause death. I consider the practical usability of my research; during my work, I laid emphasis on the detection of vehicles traveling against the traffic as well as to detect the possible dangerous road section which is potential ghost driving locations. My aim is to support traffic management by analyzing the traffic data from radio frequency system, which even provides immediate intervention to avoid congestion. My goal is also to research indoor navigation possibilities and to set up the related theoretical model and its implementation by using test measurements.

The objectives of my doctoral research were:

– supporting indoor navigation,
– warning black spots,
– detecting wrong way drivers,
– examining the transport-related applicability of nearly real-time data collected by the radio frequency system.

3. Indoor positioning and navigation

One of my aims is to investigate how the radio frequency identification system operates indoor and whether it is able to support reliable navigation system which guides the user within a building. A method to provide a new solution for indoor navigation has been developed. Indoor and outdoor propagation circumstances, the regularities and correlations between signal strength and distances have been analyzed. Based on the installed tag structure, a cell-based positioning procedure has been designed, in cooperation with the developed graph-based routing module, determining the optimal path between the starting point and the destination. The graph-based routing module is using the building's characteristic points (e.g. entrances, staircases).

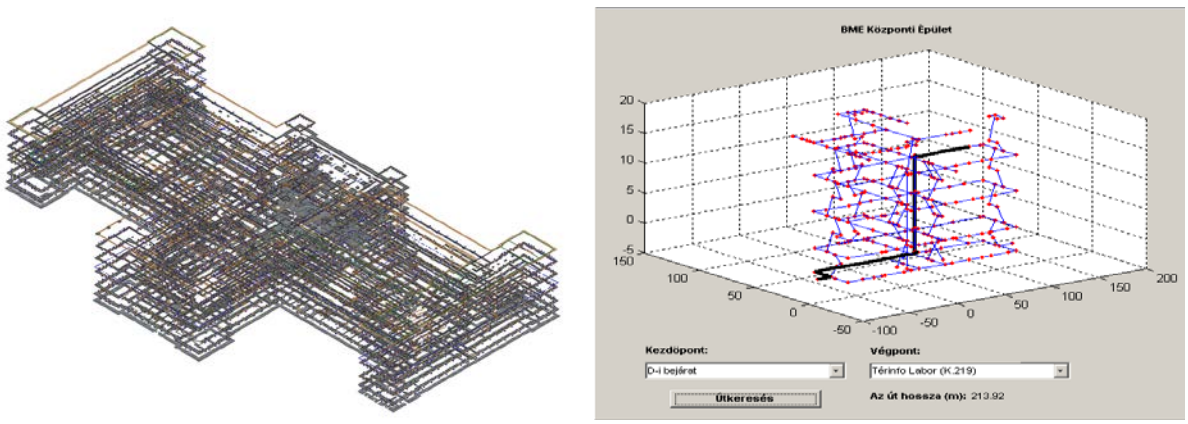


Fig. 1: Floor plan of the test building and the graph-based routing module

Thesis 1: *I have developed a method for indoor localization based on radio-frequency identification technique, which can be extended to indoor navigation.*

Related publications: (Krausz & Barsi, 2007b), (Krausz & Barsi, 2009), (Krausz, 2012)

4. Black spot warning

For outdoor applications, the main area of interest is how to increase traffic safety since traffic accidents are the leading causes of death. I have investigated the possibility of predicting dangerous road segment (accident black spots) with the radio frequency identification system. In this application, the tags provide information about the status of the road segment and drivers are able to receive important safety information in time. The moving reader is continuously scanning and getting information from the fixed tag. Radio frequency communication ensures that driver gets information even at limited or blocked visibility; the system is weather independent and not affected by the time of day. The theoretical model was verified by several tests.

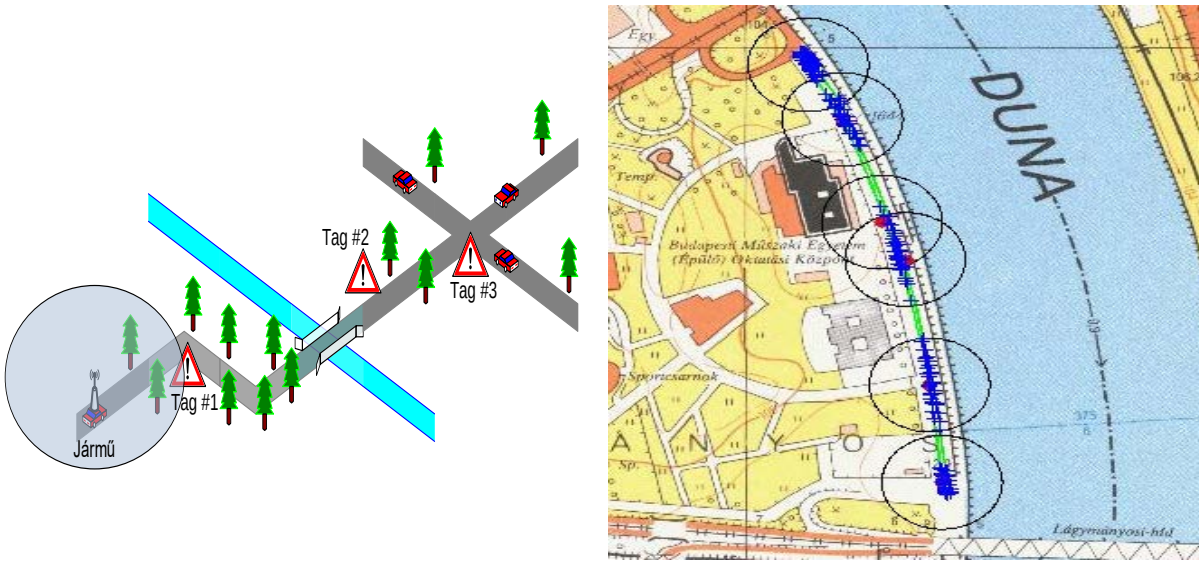


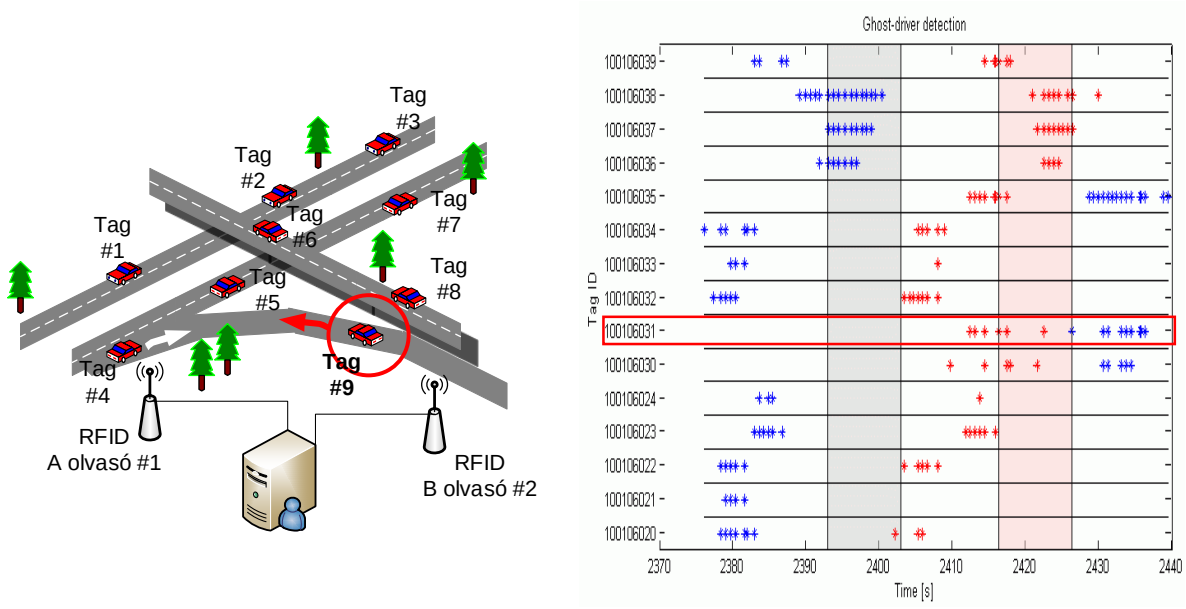
Fig. 2: Prediction of accidents black spots with moving antenna

Thesis 2: *In order to increase traffic safety, I have developed a methodology based on radio frequency identification to predict accidents black spots and its location- and device-independent practical adaptability have been proven.*

Related publications: (Krausz, 2012), (Krausz et al., 2012), (Krausz et al., 2017)

5. Ghost Driver detection

The task is to detect cars driving in a wrong-way direction. If the vehicle passes by at least two sensing points, the ghost driver can be detected with an automatic sensor and alarm system; based on the detection order, it can be decided whether the driving direction is correct or reverse. To enhance road safety, I developed radio-frequency-based automated monitoring system methodology to detect vehicles against the traffic. In the readers' range the vehicles send their identifiers – stored in their RFID chip – with a time stamp, which are then stored by the central system for a given time interval. From the incoming data an algorithm decides, which identifiers are likely to be traveling in the wrong direction. The operation and performance of the system have been proven by tests.



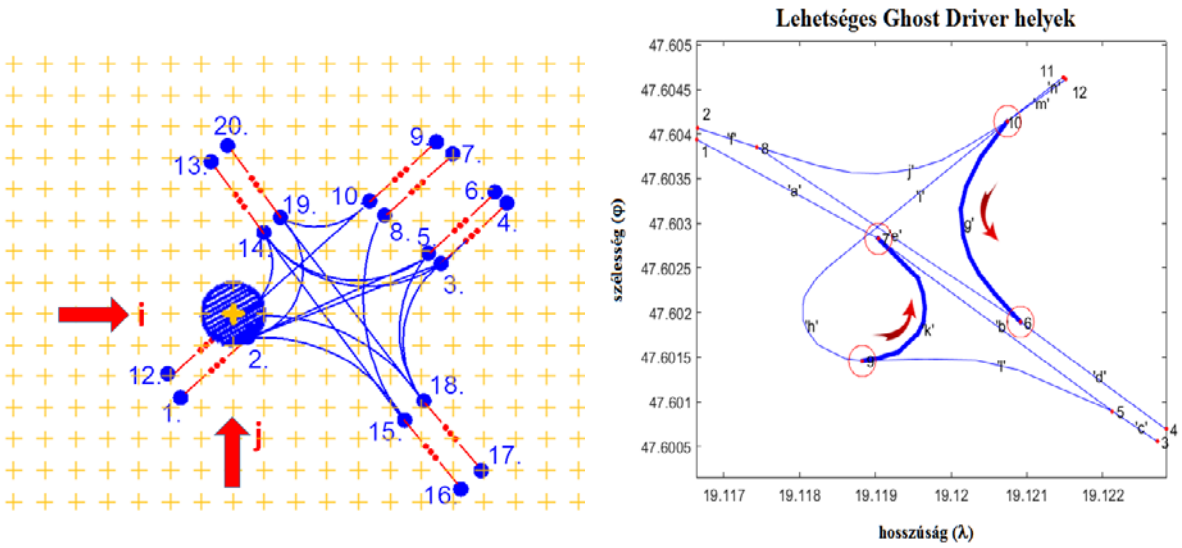
a) b)

Fig. 3: a) Schematic illustration of detecting wrong way driver
b) Detection diagram with two sensors. The ghost driver vehicle has a tag ID 100106031 marked by red frame

Thesis 3: *I have developed an automatic and real-time methodology for ghost driver vehicle detection by radio frequency identification.*

Related publications: (Krausz et al., 2017), (Krausz et al., 2009), (Krausz & Barsi, 2010), (Krausz, 2013)

The principle of automated optimized antenna layout has been provided for urban junctions to detect ghost drivers, which allows to design efficient junction monitoring network. My aim is to identify junctions based on some characteristics, in which wrong-way driving vehicles are expected because of the intersection design and topographical features. The basic assumption is that the dangerous sections can be detected based on their geometry, and therefore a deployment of automated detection system can be recommended and installed. In my investigations for the analysis, the logical structure of the selected junction has been used. The logical structure of the graph contains the minimum required number of nodes for the correct and complete mapping of the junction, so it includes all the required elements needed to represent turning, connecting and exiting rules. For visualization purposes, additional vertices are required. Several constraints were applied to form the road topology. In case of high-speed junctions, the developed algorithm is capable to provide potential ghost driving locations based on graph analysis.



a) b)

Fig. 4: a) Automated antenna positioning
b) Potential locations for ghost driving

Thesis 4: *I have developed an infrastructure planning procedure for an automatic monitoring system based on radio frequency identification to a wide range of traffic junctions to detect ghost driving vehicles.*

Related publications: (Krausz & Barsi, 2010), (Krausz & Barsi, 2016), (Krausz & Barsi, 2017a)

6. Smart city

With installed RFID readers it is possible to detect not only the wrong way drivers, but the system is able to integrate with other sensory systems to create a complex multi-sensor solution. An integrated and strategic planning of traffic and assessment of its performance is based on the size and movement of the vehicle traffic flow. The main question was what kind of data can be collected from the vehicles without disturbing the traffic, if the data is stored in an onboard memory as an electronic car document (license). In my examinations, I separated the presence sensing and the full memory reading at the specified velocity. Using installed radio frequency antennas, it is possible to check the traffic participation conditions without stopping the vehicles. Relatively large amount of information can be stored in the active tags: the type of the vehicle, number of axles, axle load etc. Using a post-processing method, the noise load, the abrasion of the road surface and many other derived parameters can be defined from the received data. The control of urban transport systems becomes more accurate based on the traffic data collected by the antennas. The system can be used for manage tolls and admittance and can be integrated into existing intelligent transport systems. With my solution, a tool for urban regulation has been offered.

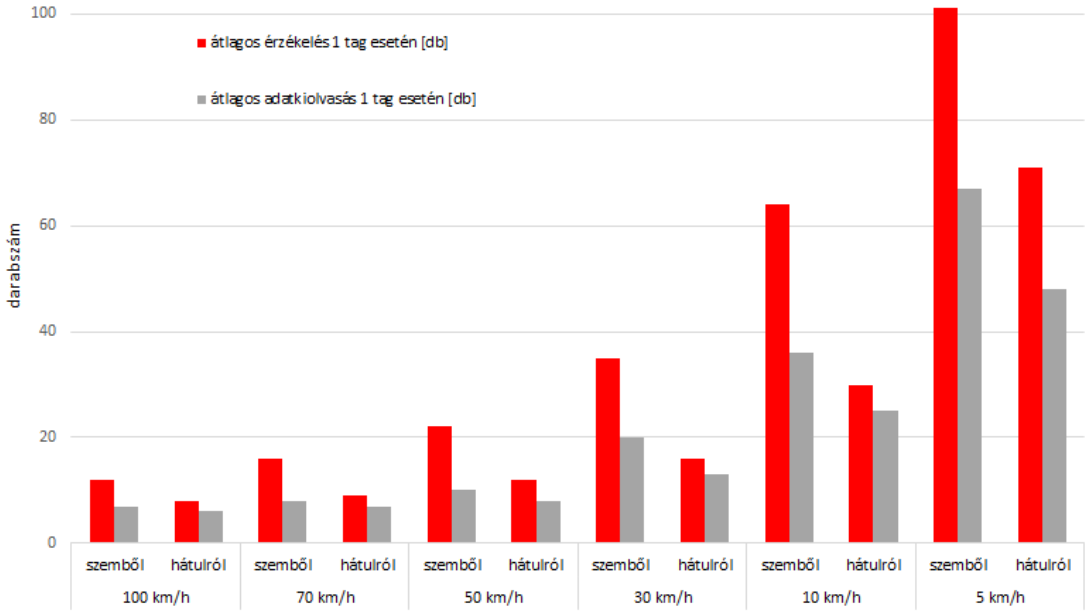


Fig. 5: Average aggregated data based on driving speed and direction

Thesis 5: *I have proven the applicability of real-time data collection by fixed radio-frequency antennas and vehicle tags in smart city transportation.*

Related publications: (Krausz & Barsi, 2007a), (Krausz, 2013), (Krausz & Barsi, 2017b)

Summary

The main reason of my PhD research was to extend the knowledge of radio frequency identification systems. The dissertation describes the measurement experiences and its conclusions with the radio frequency identification system. Using the experiential data, a cell-based positioning procedure has been designed in cooperation with the developed graph-based routing module, determining the optimal path between the starting point and the destination in indoor environment. I investigated the possibility of predicting dangerous road sections with the radio frequency identification system. One of the foci was on the detection of vehicles traveling against the traffic. Due to the specialty of the subject, as many field measurements as possible have been executed to determine the reading success in various traffic situations at different speeds with multiple cars, covering the widest sensing possibilities. A radio-frequency-based automated monitoring system methodology has been developed to detect vehicles against traffic. The working system has been tested in real environment – of course, without interfering with or compromising normal traffic – including the test track of the Fiat Research Centre. To create a sensor network for detecting improperly moving vehicles, an infrastructure planning procedure has been developed that can be applied to a wide range of traffic junctions. Finally, it has been proven that the traffic data analysis from the radio frequency identification system provides immediate intervention for the traffic management in order to avoid congestion.

The system can be used to manage tolls and admittance, and can be integrated into existing intelligent transport systems. With my solution, a tool for urban regulation has been offered.

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