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Road Problem Diagnosis with Multi-Agent Systems in Traffic

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ABSTRACT

Today, traffic problems are important factors that cause loss of life and property. The fact that the drivers are not instantly unaware of the changing road and traffic conditions prevents taking early measures and triggers traffic problems. As an alternative to the deficiencies in the existing traffic cameras and observation systems, the model has been developed with each vehicle on the road as a unit of measurement. In the study, it is aimed to evaluate and share the road and traffic conditions between vehicles with a low-budget vehicle network module and to take early measures against possible problems. In this study, an early accident prevention method is presented by using multi-factor structures to monitor vehicle flow in traffic, detect road problems and take early precautions. The road hazard detection model was developed by making the prototype of the proposed system, and the model developed for the studies, experiments and early warning system to prevent possible traffic accidents was recommended for the prevention of traffic accidents in the future.

1. INTRODUCTION

A traffic accident is an event involving one or more vehicles moving on the highway, resulting in death, injury and damage. The World Health Organization(WHO) has declared that one person dies in traffic every 24 seconds[1]. According to this information, 1.35 million people die annually in traffic accidents every year. Traffic accidents take the 8th place among the main causes of death of people[2]. In the WHO's report titled "Save Lives", it was noted that the legal measures taken by countries against risk factors for traffic accidents were insufficient and statistical studies were conducted on traffic accidents[3,4]. The "World report on the prevention of traffic accidents", jointly prepared by the WHO and World Bank, includes current information about road accidents and evaluations on what can be done about it. Traffic accidents are also one of the main problems that put a burden on the health system. When we look at the causes of traffic accidents, unsafe road infrastructure is seen as the next cause of driver errors.

The construction and maintenance of roads are important factors for the safety of people. The safety of all roads must be constantly monitored for the safety of passengers, pedestrians and vehicles. This means making sure it will provide adequate service for pedestrians, cyclists, light and heavy vehicles. Weathering caused by the movement of vehicles, infrastructure works, climatic effects such as rain and snow can be shown as the reasons that directly affect the health of the roads. In some cases, warning signs indicating the danger of landslide are used for roads on mountain sides. However, there may not be sufficient warning system for drivers and pedestrians for other unforeseen hazards. Taking precautions to prevent traffic hazards can be critical to reducing the risk of various injuries and loss of life and property. In addition, quick intervention in possible accidents, designing safer highways, using adequate information systems for road safety, creating transportation planning, improving the safety features of vehicles, making post-accident maintenance improvements, developing relevant road laws and applying them can be cited as some of the measures that can be taken.

The vast majority of traffic accidents are caused by driver and road-related negativities. Driver-related errors; Not taking precautions against road and weather conditions, excessive speed, not obeying traffic rules, driving inexperience are included. Road-related errors are caused by factors such as slippery ground and unpredictable road disturbances (Figure 1). In general, it can be said that traffic accidents occur when the movement and capabilities of the vehicle used cannot adapt to the road conditions.

Today, various solution methods are considered on the prevention of traffic accidents in different work areas. One of the fields used in solving a particular problem is multi-agent systems. It is a computer-based modeling technique used in multi-agent based traffic simulations, traffic

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transportation, and road infrastructure development applications[5]. The strength of this model lies in its ability to cope with the computational capacity of complex environments such as traffic, where the effects of individual behavior in traffic can be observed. By using multi-agent systems, applications that simulate vehicle collisions have also been made in order to improve vehicle technologies and predict future developments [6]. In order to measure the general behavior of systems in general and to reveal some behavioral models, applications are sometimes performed on simulation. In simulation programs, an icon is defined for the factor that represents many possibilities, and the simulations are run for a certain period of time until the desired result is achieved. Here, the success of the simulation depends on showing all possible real-life factors in practice. An event that is not defined in the simulation is insufficient to reveal the real success of the simulation.

However, commercial traffic simulation software currently using multi-agent architecture (eg Vissim, Aimsum) has limited capabilities in handling the causes of human-induced traffic accidents. Even the most advanced software types are incapable of analyzing some traffic events, despite the inclusion of complex elements or the examination of detailed parameter distributions that can affect traffic safety situations[7]. The reason for the inadequacy here is that the potholes or defects on the roads can be on any side of the roads. In some cases, problems arise in the same parts of the roads all the time. This results in unpredictability of exactly where and when road problems occur. As a result, it is not possible to test these unpredictable events in the simulation program. It is common for drivers who are unaware of each other to have an accident on the same route. For example; Collisions can occur when a driver who sees the defect on the road drives on another side of the road instead of driving on the rough road.

In this study, an information network model is proposed in which traffic road conditions and information are shared among drivers. The information shared in the network is shared with the central traffic units simultaneously and the traffic conditions can be followed simultaneously. In addition, changing conditions and danger situations on the road can be learned instantly and early measures can be taken. With the multi-agent model, it is possible to create risk maps of the roads. In this way, it is aimed to prevent possible traffic accidents, to intervene quickly in emergencies and to take early measures for traffic safety.

2. Using Multi-Agent Systems

In recent years, Multi-Agent System (MAS) structures are a new field of study used to produce solutions in intelligent applications with complex solutions. In addition, it is seen that this working discipline is a solution area that is applied in different fields of study [8-12]. Multi-agent systems are computer-based rich problem solving techniques that express the problem solver processors to solve problems that they cannot solve on their own, by cooperating together [13-15]. In other words, agent-based modeling is used to express and explain computationally complex systems that cannot be easily described by mathematical equations. In other words, they are computer systems that are in a certain working environment and can show autonomous behavior in this environment in order to fulfill their common tasks [16].

Figure 1. Road problems damage vehicles and cause traffic accidents.

The general purpose of MAS systems is to distribute the workload to different agents for solving and calculating the problem in large and large environments. MAS systems are prone to produce solutions in cloud systems with their structures[17]. Cloud systems are applications that use informatics and are based on communication with remote systems [18]. In the cloud system, a structure is established in which data can be accessed remotely without the need to install any program [19]. In cloud-based systems, there is a lot of real-time communication between devices. In MAS, every device is interconnected with a predefined set of features and tasks. This organization provides a suitable high-performance infrastructure to handle large-scale data processing and applications, and provides a controllable platform for distributed computation of data [20,21]. In addition, simulating objects as intelligent reactive agents enables real-time adjustment of control parameters in cloud-based systems and complex interconnected networks. Having such features enables MAS systems to be used in multi-layered network structures [22].

The characteristics of the agent structures and the characteristics of the traffic elements are similar. In Figure 2, the use of vehicles as a building block of the MAS is shown. In multi-agent systems, involuntary departure of a single agent from the system cannot lead to fatal crashes or cause the system to crash. For this reason, it is not expected that the vehicles entering and leaving the traffic will cause a negative effect in the operation of the system in general. In terms of using expert systems within MAS structures and providing flexibility in evaluation and control applications, it also brings with it a number of solutions in terms of originality and security for the user. MAS structures can be used throughout the traffic system, as well as locally in a region or for purposes such as controlling the road construction in a particular area of special importance. Measuring agent behavior is an important factor in establishing the internal mechanism between agents and understanding the overall system functioning. It is thought to be a useful approach in managing the hazards foreseen in the simulations to be created and finding solutions[23]. The use of multi-agent systems, which is one of the distributed AI(Artificial Intelligence) fields, has been proposed as a solution for traffic signal control problems, which is seen as one of the complex problems in traffic [24,25]. Some of the studies have handled traffic scenarios about collision events in traffic where objects such as people and vehicles are modeled in practice[26-29]. It is a useful practice to make some improvements in traffic safety and in improving traffic flow by using multi-factor applications and monitoring the travels of vehicles in traffic. With such applications, it is aimed to solve traffic problems in the future. The structure of multiple factors can be seen as an ideal solution area for the traffic environment that contains too many parameters and problems, as in the reasons explained here.

3. Identify Road Problems

Recently, fault detection and diagnosis of important and complex hardware at critical points can be made uniquely with multi-agent systems and monitored via remote communication network. It may be possible for this system to provide overall road safety for the movement of vehicles in traffic and to take early measures for possible accidents and hazards. In this system, where vehicles moving on the highway are connected wirelessly with each other and with the central server, it may be possible to evaluate the analysis of highways spread over a wide geography as a whole(Figure 2). As a matter of fact, studies have shown that MAS systems can also be used as a solution in wireless devices[14].

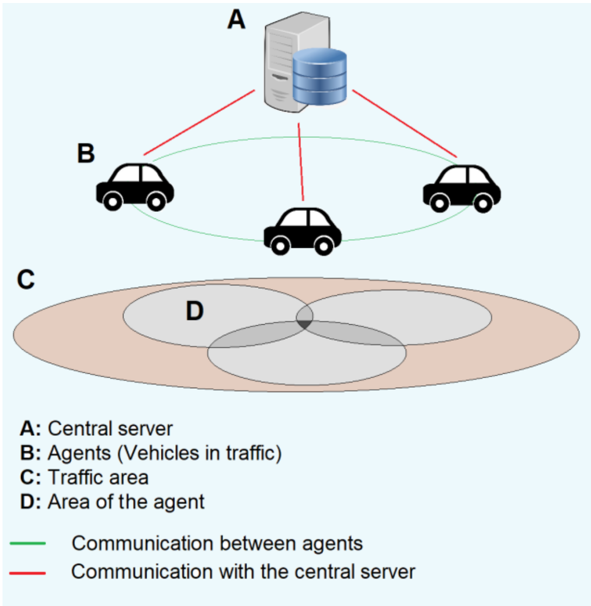


Figure 2. Multi-agent system diagram for vehicles in traffic

In this structure, the factors can be found in the area they are responsible for (fault environment) in intersection with areas dominated by other factors. Different vehicles may be traveling on the same road. It may not be possible for another vehicle to detect a disturbance in the road while a vehicle is in motion. This is because different vehicles have different sub-equipment. However, if most of the vehicles traveling on a certain route are affected by the road problem in a certain area, it can be diagnosed within the system that there is a problem on the relevant route. As a result, a single information helps to reach more clear and reliable results as long as meaningful correlations can be established with other information. The system works over the GPS-based road condition measurement unit placed on the vehicles. Every vehicle in traffic is included in the system and is in communication with the main server and other vehicles. The measurement unit communicates with the remote server thanks to Lora modules with a communication range of 7 km. When a vehicle with a road condition unit encounters a bad road structure (pits, slips, stones, etc.) on the route it is on, the vibration in the vehicle is detected by the acceleration sensor on the unit (Figure 3). The acceleration information obtained is processed by the ARM-based STM32F407 microcontroller to determine which road disturbance the acceleration information belongs to and its severity. Here, the instantaneous road health information (RHS) on a certain route is calculated speed related (V) of the vehicle moving on the highway, the horizontal and vertical accelerations(a_x, a_y)while driving, and the mass((m_v) of the vehicle(1):

$$RHI = V^2 a_y a_x m_v \tag{1}$$

The Road Health Information (RHI) obtained here is the information that a single vehicle calculates at a certain coordinate. In the factored system, the overall Road Health Status (RHS) obtained as a result of the road measurement of each vehicle is calculated as follows (2):

$$RHS = \frac{\sum V^2 a_x a_y m_v}{V_n} \tag{2}$$

The health status of a point on a particular highway on the system is calculated with the average of the general measurement information, depending on the number of vehicles (V_n) passing through the relevant coordinate and measuring Road Health Information (RHI). If the acceleration intensity is above a certain threshold value, the acceleration intensity and road problem information is transmitted to the central server and the problem on the relevant coordinate is recorded by the server. If similar road problem information is detected by different vehicles at different times on the same route and transmitted to the central server, the information that there is a problem on the relevant route is confirmed by the central server. This information obtained is stored in a cloud information network. After the finalized information, a common message is sent to all vehicles included in the system about the relevant route, and information about the problematic route is broadcast. In this way, the driver of the vehicle approaching the problematic route is warned audibly by the road status unit on the vehicle while approaching the relevant route, and precautions are taken for possible traffic accidents.

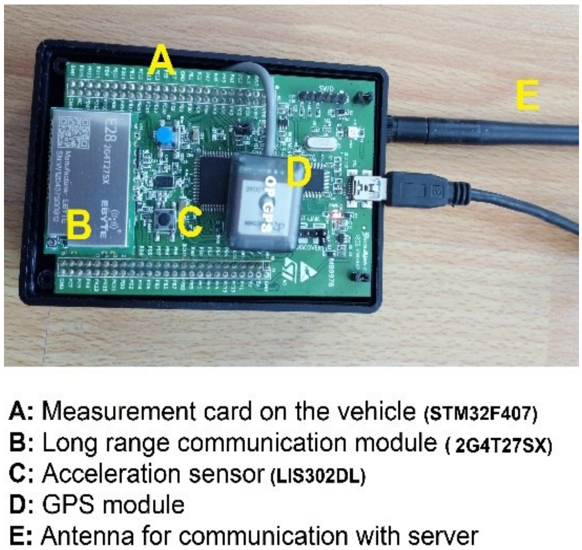
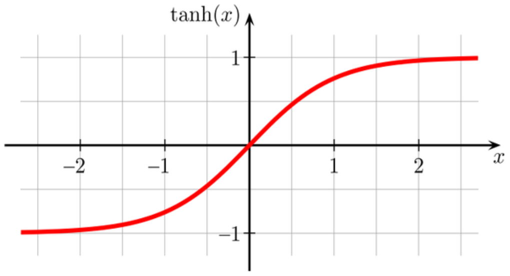


Figure 3. Measuring unit for detection of road problems

The data received from the module may not be at the same level in every vehicle. Since the detection of road defects such as potholes and bumps will be at different levels depending on the vehicle's speed, weight and other conditions, the hyperbolic tangent activation function was used for road risk detection (Figure 4). Highway threat information is received as positive-negative acceleration data from the acceleration sensor. The acceleration information obtained is passed through this function and compared with a certain threshold value. Values of 0 and close to 0 indicate that the vehicle in motion does not encounter any threat on the highway. The threshold value is determined as a level that will endanger highway transportation and vehicle safety. Since the threshold level will depend on the speed of the highway vehicle, the type of vehicle (transport, public transportation or private vehicle), weather conditions, and the risk coefficient of the relevant road, it will not be at the same level on every road. For this reason, the danger threshold coefficient for the highway is used on the map so that the road problem information obtained from any coordinate is not considered as a direct danger. Accordingly, when a certain number of problem information regarding the highway section in a certain coordinate is received, it will be understood that the relevant road has reached the level that will endanger the highway safety, and an exit is generated to take the necessary measures.



$$\tanh(x) = \frac{e^{x} - e^{-x}}{e^{x} + e^{-x}}$$

Figure 4. Hyperbolic tangent activation function

A measurement and vehicle information tracking program was prepared using C# programming language. The C# program integrates road condition datas from multiple traffic factors, including the interaction between vehicles, drivers, and all. The traffic agent is modeled to act autonomously in accordance with real life in order to create literal traffic flow. The prepared C# program was implemented to simulate the flowing traffic involving hundreds of vehicles at anytime in a designated area in the city of Izmir (Turkiye). Since the simulation programs cannot predict every parameter and human behavior in the traffic, the application has been carried out with many realistic measurements on a certain route. For example; The movement behavior of the public transportation vehicle on the road is different from other vehicles. Because these vehicles have to stop at certain points on a certain route and have to approach the roadside. This behavior also distinguishes it from vehicles using a certain part of the road on the highway. The prepared C# measurement observation program is capable of remotely processing the data received from the measurement module on the vehicle. Here, every vehicle can be followed instantly, while acceleration information on the road can be followed in real time (Figure 5).

4. Conclusions

With the proposed method in this study, a road control system model using a multi-agent structure has been proposed as an alternative to the deficiencies in today's traffic road control and safety practices. In the study, the measurement module integrated on the Fiat Fiorino model vehicle was used. The measurement module is built on the STM32F407 microcontroller based development board with ARM architecture. This development board has instantaneous acceleration measurement and 168Mhz processing speed that can transmit this information wirelessly, a built-in accelerometer sensor and a 7km range transceiver module. The vehicle has a length of 3.86m, a width of 1.71m, a weight of 1.45 tons, a rim diameter of 16 inch and a tire base width of 195mm. The measurement module is built into this vehicle on the dashboard. With the low-budget road control modules to be integrated into the vehicles, the control of the road conditions is monitored in real time, while the vehicles included in the system are instantly informed about the road conditions. The system works as an information network between vehicles. In addition, the detection of the road problem on a certain route by the vehicle moving on the route ensures that the problem here is monitored by the system and instantaneously. Thanks to the program developed with the movement of the vehicles on the road and the active structure created, the road acceleration information of the vehicles is obtained (Figure 6).

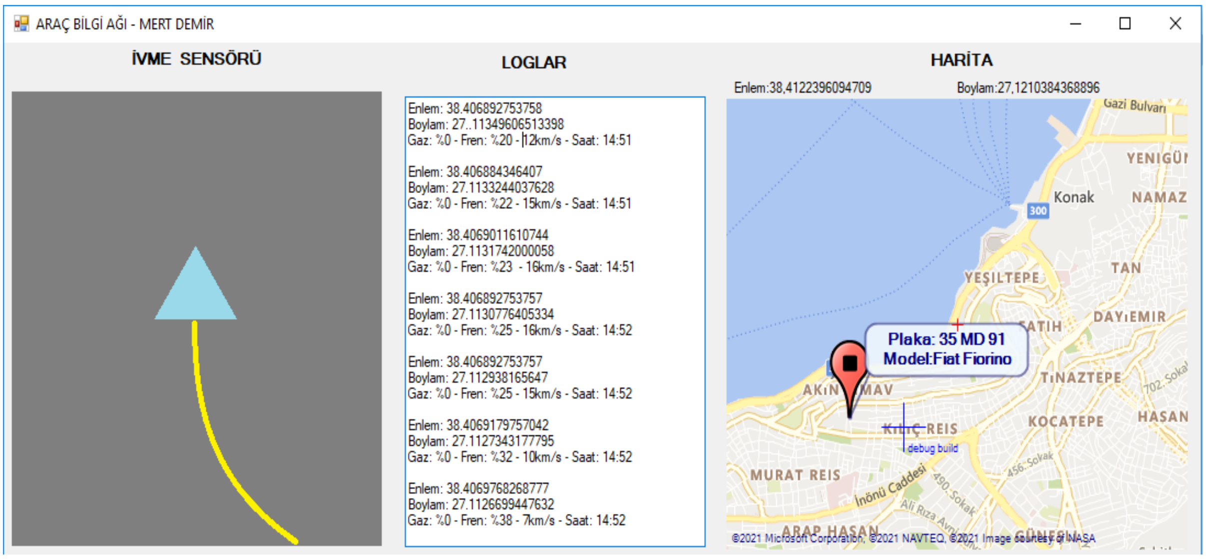


Figure 5. Problems on the roads are recorded by the road condition unit

In this way, it is aimed to take early measures by detecting minor problems that occur on the roads before possible accidents occur in road-related problems. In addition to road problems, situations such as sudden braking of vehicles in traffic and unexpected events on the routes can be followed.

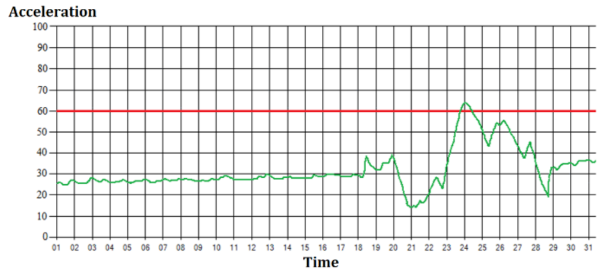


Figure 6. Acceleration changes of the vehicle in motion due to the disturbance on the road

According to the observations made in the study, it was seen that the road problems in the middle of the road were less perceived, while the more used sections of the road, the street intersections had more road problems. The reason for this is that there is a height difference at the intersection of two roads as a result of asphalt works done at different times. It has been observed that road collapses, which are one of the road problems in particular, occur in the areas where the vehicle wheels come into contact the most. The basic approach applied in the study presented here is based on the increase in wear on the road over time and the need for road maintenance when growing problems exceed a certain threshold level. In the experiments, the vehicle speed was maximum 40 km/h and the information about the driving tests is as seen in Figure 5. With this vehicle, driving was carried out on the roads with colored dots on Figure 7 and Figure 8. In the experiments, two drives were carried out to observe the difference between the measurement threshold values. In addition, in the methodology proposed here, as a result of the acceleration measurements increasing depending on the speed, a speed limit for each route will be useful in the implementation of the model here and in ensuring traffic safety in order to avoid this result, since damaged road information may result from vibration on a smooth road. As a result of keeping the road problem detection threshold value high in the first methodology, only very serious road problems that cause serious vibration for the vehicle were detected (Figure 7). In the second methodology, as a result of lowering the road problem detection threshold value, besides the road problems, small road potholes that are likely to cause problems in the future are also detected (Figure 8).

Based on this information, it is possible to detect and track small problems that are likely to grow in the future due to road wear. With the cloud information structure created here, it is ensured that all drivers are informed of the defects that have occurred on the road.

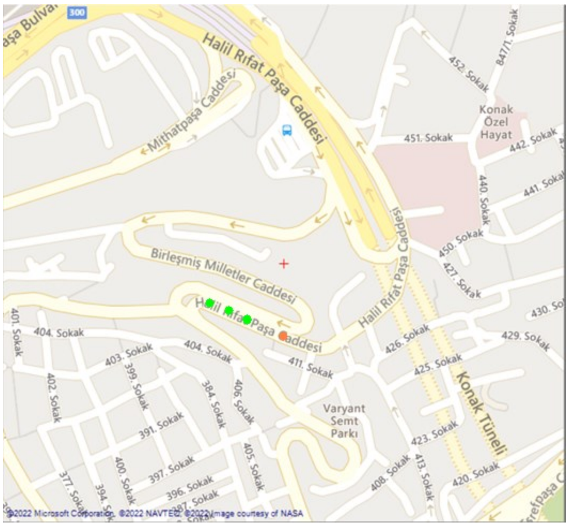


Figure 7. Detection of road problems by keeping the threshold level high (Green point: low risk, orange: medium risk route)

Accordingly, by notifying the drivers of the road defect previously determined for a certain part of the road, the drivers were enabled to drive more carefully in this part of the road. The strength of the method proposed in the study is its sufficiency to measure the ability of MAS systems in a wide variety of traffic conditions directly derived from the relevant factual traffic environment, involving near-miss traffic collisions, sudden starts and braking, and collisions.

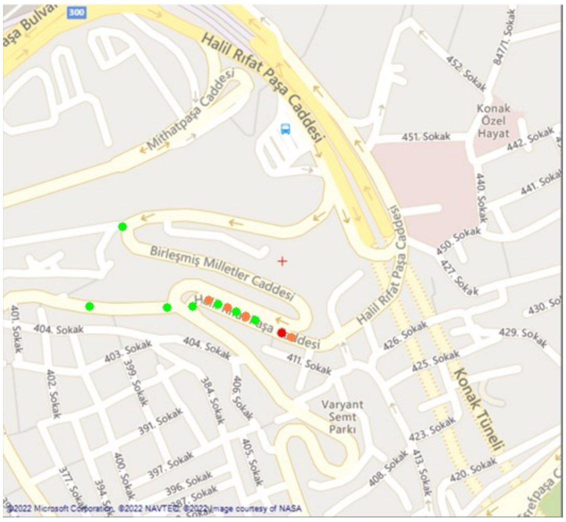


Figure 8. More precise road measurement by keeping the threshold level low (red: high risk route requiring road maintenance)

The current work is focused on developing a limited domain based program and methodology for the real-time implemented MAS system, which is taken out of the simulation environment and includes only the drivers and the cars they drive. As a result, a multi agent road safety simulation methodology has been developed to predict the safety impact of different size and weight highway vehicle technologies. In addition, applied MAS work can anticipate potential future problems and take necessary action, and can therefore provide useful information for developing research and policy-making strategies that accelerate security improvements. These estimates can be used to ensure the safety of life and property, to analyze the economic losses caused by traffic accidents and to take measures in this regard (Figure 9).

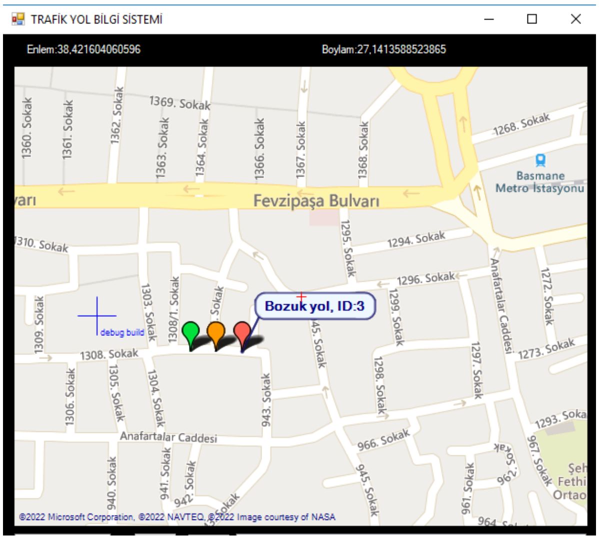


Figure 9. Road problems are categorized by the server on the map

Author's Note

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