ACTIVE TRAFFIC GUIDANCE DATA SYSTEM

AKTĪVĀ SATIKSMES VADĪBAS DATU SISTĒMA

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Introduction

Everybody knows importance of the traffic safety [1]. So the defined task is to design a system, that is capable to control the traffic wherever it is. The system must handle situations with high speeds, different directions, jams and so on. Algorithms behind it, must be fast and universal for every case on the lane.

Coordinate system

All other systems, that are dedicated for traffic control, use global positioning system, that is good enough for vehicle tracking, but no sufficient for dynamic traffic safety system. So the definition of coordinate system is extension of GPS. While it is difficult to acquire very precise coordinates on move, each object must have them predefined. So each street, crossing, bridge has its coordinate entry that is independent from satellite visibility conditions. Required level of scale division – 50 cm. This division comes from vehicle controller selectivity described below.

Vehicle in coordinate system

Each vehicle has its coordinates according to global grid. In each moment each vehicle can change its position or stay on place. So all vehicles have to have a table with current coordinate entry. While moving, coordinate value change and it is possible to assign a vector to the vehicle. Vector value is the distance, the car does in time division. Direction of the vector is expressed as angle relative to direction North. So direction N = 0 degrees, direction east E=90 deg, S=180, W=270. So entry describing vector will contain 3 bytes of digits, that give vector length, where 3 places are before decimal divider. Current coordinate contain 8 bytes, and angle – 3 bytes. Each vehicle also has its safety zone shown with vector R. (Fig. 1.) So, if the car is moving in the city, where time division is 0,1 sec with 15 m/s (54 km/h) and is heading somewhere between north and west with angle 318,731° and current coordinates are N54°23'25"4120 E22°56'44"6219, the 21-byte table entry in hexadecimal system will look like 00 10 0F 00 01 3E 2D B4 E3 61 71 91 01 84 51 63 82 C1 84 B0 0F, where ending 00F is safety zone radius.

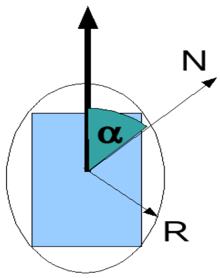

Fig. 1. Schematic representation of vehicle and vectors.

Lanes in coordinate system

While each street, road or highway has coordinates of its beginning an the end, it is possible to give a direction vector to it. At the beginning of the street, from built-in transponder, car get the information about current lane. So we can predefine certain safety recommendations. That mean, maximum recommended vector value of the occupying car, lane direction in degrees according to direction to North. So to keep the track direction of vectors must match. In curves a passive transponder [2] can give information about radius and distance to the next transponder. On streets with lanes more than one, it also contain lane number where smallest number describe outer one. So passive transponder memory must contain value of described above and look like as example – time division equal to 0,1 sec, maximum recommended vector size 13,80 m/s, direction angle 156,226º and coordinates N54º23'26"0001 E22º56'45"1212. Value in hex is 00 10 0D 50 34 20 E2 4E 36 17 1A 00 01 45 16 38 2D 4B C1 A0 20 00 00. In the underlined part 1 is the lane number, A02 distance to next transponder, 0 mean straight (1 in this position mean curve) and tailing zeros occupy place for curve radius.

Algorithms

Main algorithm does only one simple operation. It make the cyclic calculation of vehicle position. If the beginning coordinates, direction and speed are known, there is no problem to calculate the position after time division. In the intense traffic it is important to know what can happen after certain time, so the algorithm can calculate possible positions after 100 or more time periods. So if all traffic participants can calculate their position after a while, it make possible to predict a dangerous situation and avoid it before something serious appear. This time period, when cars calculate and exchange they position information is named Time of Interest (further TIO). Let's look at some typical situations.

- Two cars are driving side by side on their lanes (Fig.2a.). While direction vectors are not directed

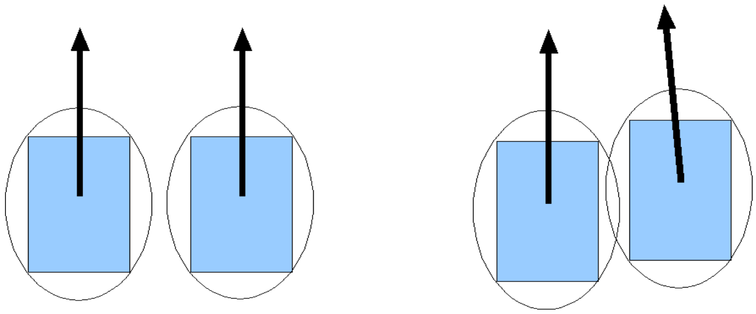

Fig. 2a and 2b vehicle positions on lanes

toward each other, situation is normal and no danger is predicted. When one of the cars start to move away from the lane (Fig. 2b), prediction algorithms show the dangerous approach (shown as overlay of safety radius vector field) and both drivers receive warning (data exchange technology is described later in this paper).

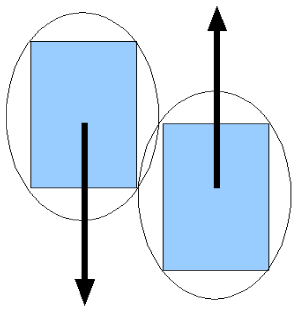

Fig. 3. Vehicle position moving in opposite directions.

- Two cars are moving in reverse directions (Fig. 3). If cars announces opposite directions, there is no problem for algorithm to predict the situation because distance or interval between vehicles must be equal or more than sum of safety radius vectors of these cars. If safety vector fields overlay, a warning appear. In fact there is no big difference between first situation and this. Difference is only in TIO, because we do not care about passed vehicles.
- Car is moving behind another. (Fig. 4.). In this case algorithm show the change of distance, and

when it is too short, a warning appear. When more than two vehicles are heading one direction, position of next another vehicles are important because sometimes early braking can avoid sequential crash when first in the column slow down extremely.

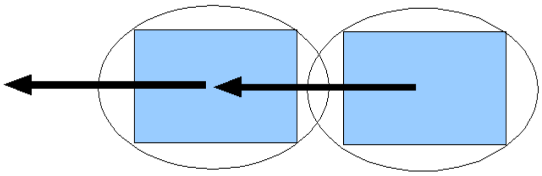

Fig. 4. Vehicle sequential position

- Dense traffic condition as shown in Fig. 5. where car O is the observer. Position and vector of each car, that is in Area Of Interest (AOI), is acquired and written to observers table for comparison. Area of interest is oval with longest radius is pi times longer than shortest and shortest is equal to distance required to stop vehicle from current speed on current road conditions. So in Fig. 5. vehicles labeled 1 to 9 are within interest area of the observer. Time of interest define, how many tables will on board controller contain. It is not functional to accumulate more data because calculations for each vehicle consume CPU cycles. In operation observer calculate change of it's coordinates and possible coordinates of other vehicles within AOI. Tables with expired TOI are deleted.

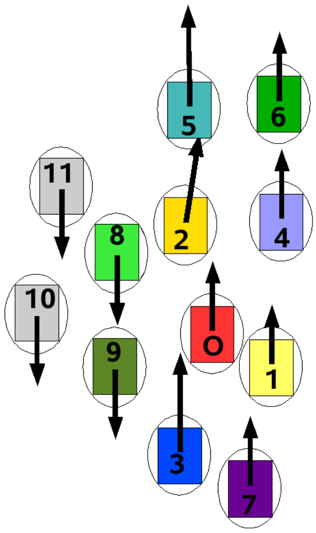

Fig. 5. A group of vehicles occupying different lanes

- In situations, when there are no vehicles within AOI, Extended AOI can take place. In EAOI all cars, but not more than ten closest, that are within 30 second travel distance, are logged in coordinate table and calculated. As example for speed 120 km/h 30 second mean distance 1 km, so all cars in 1 km radius ahead will be logged. EAOI is useful in countryside, where narrow and twisty roads limits visibility and information about aproaching vehicle can minimize risk of crash. It is also useful on empty highways, where traveling speeds are very high and careless drivers are dangerous to others and themselves.
- Another serious moment is – when active guidance system is broken, turned off or malfunctioning. All cars, that use system must be supplied with distance sensors. If

distance sensor "see" a vehicle ahead, then check routine read the values in table to identify a vehicle within AOI. There is no need of very exact values so if table entry check return a value, that is within certain limits, it is possible to assume, that everything is OK. When this value appear to be greater than it is an errorneous state and negotiation routine must be run. As example from fig. 5. A vehicle (2) is 5 meters ahead of observer, as reported from distance sensors. Add extra 3 meters of possible car length to coordinate center. So in observers AOI table must be entry with coordinates of that vehicle within 11 meters ahead (distance plus car length). If there is no entry, observer check the position of next possible vehicle in front. So it read the coordinate of vehicle 5. After that a request for vehicle 5 is generated and request information about distance to vehicle driving behind (2). If vehicle 5 reports the distance to vehicle 2 and delivers a AOI table status GOOD, then observer can assume, that vehicle ahead is a long and update its AOI table according calculations. In normal operation this situation can appear, when data transmission from section host is disturbed. If vehicle 5 reports distance to vehicle 2 (closest behind) and there is no entry in AOI table, both vehicles can assume, that object has broken system and calculated virtual entries have been put in AOI table. These entries will be transferred to host with flag ALIEN. This algorithm permits to detect and predict motion of the vehicle that is disabled for automatic recognition.

Data transmission technique

While system is very mobile and dynamic, regular protocols are not sufficient for communication purpose. My proposal is to create a dedicated protocol named Vehicle Communication Control Protocol (VCCP). It is a certain derivate of transfer control protocol (TCP) used in internet communication. Within this protocol all transmission data is encapsulated. The VCCP packet can contain payload of coordinates, status information, both of them, and private key exchange. When coordinate information is delivered to VCCP, a checksum is calculated and added. After all packet is encrypted with dynamic session key. Encryption is mandatory to avoid any third party intervention or interception. So protocol must be secure by default. While there is no need to transfer information elsewhere than between host and vehicle, there is no need for expensive fixed network. An option is also possible – each traffic light controller may have it's own receiver so timing can be adjusted according situation. For example – if there are vehicles on street one, but none on street two, a red light on street one will not appear until a car or pedestrian request comes for street two.

Data between vehicle and host is radio wave carried and consume TDMA (Time Division Multiple Access) algorithm.

Field divisions

Whole surface of certain area is described with coordinate grid and each part of this grid is assigned to Host. Host device is computing complex, that has enough incoming data transfer channels, to gather data from all vehicles simultaneously. Host device make parallel calculations and compare result with received data. Host device has very strict borders and have no overlay areas with neighbor segment. When vehicle travel from one segment to another, a notice is sent to neighbor host and reply to coordinate announcement, that is received by, for example, host1, comes from host2. So vehicle on board system has semi automatic handshake with next host device. Each host will have eight neighbors maximum. For exactness of situations, borders are outside crossings but very close – mean, street one cross street two, then host one control street one and crossing, but street two is controlled by host two. Vehicle on board device also can get information about lights ahead and in heavy traffic conditions start braking for red light as soon as needed.

Transmission directions

After generation of current position coordinates and direction vector this information is unicasted to sector host. If no sector host is announced or no acknowledgment received, this information will be broadcasted in another data transmission channel. This transmission channel is common for all vehicles. While VCCP packet contain host key, only vehicles within current host segment will receive and decode this packet correctly. Other can not decrypt packet and understand it as not usable, so all data will be dropped. Host system after receiving such broadcast also send unicast acknowledgment as in normal situation. In case of answer to broadcast, a reply request flag is activated and vehicle must reply with acknowledgment and retransmit current coordinates.
In case of host device breakdown, a hotspare backup will start operation. In places without host, cars do not receive acknowledgments. So if incoming transmission is from broadcast, and more than one vehicle announces its coordinates this way, a backup transmission algorithm take place. In Layer 2 according to OSI the system uses token so all vehicles broadcast their data in sequence. All cars has VCCP ID received from host and car with smallest ID has first hand and start token run.
After vehicle on board system update its AOI table with new data, a command may appear in DbW controller. In modern vehicles, where DbW implementation exist, adjustment for safety can be done. When prediction show dangerous situation, actuators can intervent driver activities and apply brakes or adjust steering. Because DbW systems have wheel position sensors, a vector direction can be calculated and announced before coordinate tracking does it.

Test facility

For solution testing purposes a test facility has been set up. It consists of two cars equipped with distance sensors connected to modified rally computer Terratrip 303 and actual position sensor is a global positioning device Garmin Explorer both connected to laptop computer. On laptop computer with Linux OS position calculation software is running and send data to host server. Host server is connected to internet and reachable via GPRS connection. GPRS connection baud rate - 9600. Both cars announce actual coordinates in two directions - via GPRS to host and via wireless ethernet (802.11b) to another car. Data calculations interval is 0.1 sec and logging entry each 2 sec. A log contain AOI table entry.
Testing give a result that match expectations. Prediction deviance is within 50 cm distance. While distance between cars with wireless connection do not exceed 100 m in the city, direct transmission was OK. Report delay from host server averages at 0,5 sec with best time 0,17 sec and worst 3,8. This delay is caused by internet conditions.

Conclusion

Active traffic guidance data system is very useful when implemented on large areas and all vehicles. This allow to predict and avoid almost all dangerous situations – crossing bypass at red light, extreme braking ahead causes sequential crash, driving out from blind corner. Even more - it permit to build a autoadaptive citywide traffic light regulation eliminating unwanted stops.

References

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Krūmiņš O. Aktīvā satiksmes vadības datu sistēma.
Šajā publikācijā aprakstīti tehnoloģiskie risinājumi, kas ievērojami paaugstinātu satiksmes drošību ļoti intensīvas kustības apstākļos. Tāpat iespējams paaugstināt kustības drošību ceļa posmos bez kustības ātruma ierobežojuma. Tehnoloģiskais risinājums balstīts uz principu, ka katrs satiksmes dalībnieks tiek identificēts ar tehnikai viegli saprotamu parametru kopu – kustības vektoru un koordināti telpā. Tāpat koordinātu sistēmā tiek apzīmēti arī visi nekustīgie elementi. Aktīvās datu sistēmas galvenais uzdevums ir, izmantojot dažādus kustības parametrus, prognozēt situāciju un novērst potenciāli bīstamas situācijas. Algoritmu pamatā ir piesaiste globālajam koordinātu tīklam, kas ļauj izveidot viennozīmīgu adresāciju. Aparāttehnisko bāzi veido skaitļošanas ierīces, kas savstarpēji savienotas ar bezvadu datu pārraides tīklu. Tās veic neatkarīgu un paralēlu skaitļošanu ar secīgu datu salīdzināšanu, tādējādi pēc mažoritātes principa izslēdzot nekorektos datus. Izveidotajā testu vidē tika iegūts sistēmas darbspēju apstiprinājums, kā arī norādes uz attīstāmajām tehnoloģijām. Ir pareizs pieņēmums, ka TDMA princips jāizmanto datu pārraidei starp objektiem. Balstoties uz šādas sistemas sniegtajiem datiem, iespējams veidot attīstītākus navigācijas un automātiskās stūrēšanas risinājumus, jo nereti piesaiste globālās pozicionēšanas (GPS) tīklam nav pietiekami precīza.

Krumins O., Active traffic guidance data system.
The paper describes the technologies and algorithms for improvement of safety conditions in heavy traffic on high-speed sections. It is also possible to improve the safety on the highways without speed limitations. The proposed technological solution is based on the principle that each traffic participant can be identified by easily readable and understandable parameters - such as the motion vector and the spatial coordinates. The same descriptive data are also given for all passive traffic elements like roads, crossings, etc. The main task of the active data system is to predict and avoid dangerous situations on the roads using specially developed data matrices. The system algorithm is based on the global coordinate grid allowing for creation of a solid and unbiased addressing system. The hardware applied in the work is formed by wireless computer grid allowing for parallel calculations and comparison of the data with wrong data elimination. For testing the system an experimental setup has been

designed. In the formed testing medium the proof for the system feasibility has been obtained, with the indication to the technologies that require more detailed revision. It was proved also that the Time Division Multiple Access (TDMA) principle can be used for data transmission between objects. Based on the data obtained for similar systems it is possible to create more advanced navigation and improve drive-by-wire solutions for automatic steering, since the global positioning system gives insufficiently precise results.

Круминьш О., Активная система данных управление активным дорожным движением.
В данной публикации описаны технологические решения, которые существенно повысили бы безопасность движения в обстоятельствах движения повышенной интенсивности. Также возможно повысить безопасность движения на участках дороги без ограничения скорости. Технологическое решение основывается на принципе, что каждый участник дорожного движения идентифицируется по легко понятной технике общности параметров- вектору движения и координатам в пространстве. Также на системе координат обозначены все неподвижные элементы. Главная задача активной системы данных,- это использовать различные параметры движения для того, чтобы прогнозироваться ситуацию и избежать потенциально опасных ситуаций. В основе алгоритма лежит привязка к глобальной сети координат, что позволяет создать однозначную адресацию. Аппаратно-техническую базу формируют вычислительные устройства, которые объединены между собой беспроводной сетью передачи данных. Эти устройства производят независимый и параллельный счёт с последовательным сравнением данных, таким образом на принципе большинства исключая некорректные данные. В сформированной тестовой среде было получено подтверждение работоспособности системы, а также указание на развивающиеся технологии. Верно допущение, что принцип TDMA можно использовать для передачи данных между объектами. Основываясь на полученных в подобных системах данных, возможно получить более развитые навигационные решения и решения для автопилота, потому что нередко привязка к сети GPS недостаточно точная.