Intelligent Transportation Systems and Vehicular Sensor Networks: A Transportation Quality Adaptive Algorithmic Approach

Anastasia-Dimitra Lipitakis¹ and Evangelia A.E.C. Lipitakis²

(¹Department of Informatics and Telematics, Harokopio University, Athens, Hellas adlipita@hua.gr
(²Kent Business School, University of Kent, Canterbury, England leacynthialipitakis@yahoo.com

Abstract

An adaptive algorithmic procedure for a proactive knowledge based intelligent transportation system based on vehicular sensor networks is presented. This algorithm operates by collecting information from certain vehicles and infrastructure objects through vehicular sensor networks by using intelligent processing, integrating knowledge and experience and issuing directives to drivers facilitating transportation quality. The efficient operability of this algorithm can be demonstrated by related simulations showing improvement in the transportation quality.

Keywords and Phrases: intelligence transportation, adaptive algorithms, sensor networks, transportation quality, artificial intelligence, simulation and modelling

1. Introduction

The rapidly extended research topic of Future Internet containing complex network infrastructures, advanced managerial telecommunication techniques, intelligent transportation systems, development and integration of novel services and applications of information and communication technologies it is expected to affect greatly every aspect of human activities, the connection of people, content and things, at multiple levels of culture, scientific, technological, economical, industrial, military applications, and social activities globally (Hasselbring and Reussner, 2006; EFII, 2010; Project E3 2009; Akylidiz et al., 2002; Jurgensohn and Kolrep, 2009, Penrose, 1989; Berners-Lee, 1989).

In recent years considerable research effort has been focused in the area of intelligent transportation systems, containing efficient systems of transportation-traffic-emergency management, revealing several inefficiencies in transportation infrastructures, traffic emergencies-accidents-congestions by using advanced information and communication technologies. These systems are operating by collecting related information from various sources, such as infrastructure objects, vehicles, through vehicular sensor networks, processing and integrating knowledge and past experience and issuing related directives facilitating the safe and quick transportation.

The Future Internet area of applications provides several mechanisms for allowing the overcome of various structural limitations of telecommunications infrastructures and their management systems facilitating design, development and efficient integration of related advanced services and applications (Jondral, 2007; Kephart and Chess, 2003). Transportation systems are considered to be key services with effective mobile services and applications for traffic networks allowing the intercommunication of vehicles, roadside base stations, by using vehicles to infrastructure communications for safer and efficient transportation (Dimitrakopoulos et al., 2010; Ebner et al., 2001).

Some advanced transportation management approaches have been recently proposed, combining (i) use of wireless sensors placed on vehicles and on predetermined parts of transportation infrastructure, such as road signs, traffic lights, (ii) wireless sensor networks (vehicular sensor networks), such as neighbouring vehicles, selected infrastructure parts and (iii) info-evaluation points proactively issuing directives for drivers and overall transportation infrastructure personnel.

Knowledge based decision making algorithms increasing the overall levels of safety and improving the total transportation quality can be used recognizing potential emergencies a priori. Furthermore, the integration of advantages of vehicular sensor networks in the intelligence transportation systems incorporating several
applications and services can also improve the transportation quality (Dimitrakopoulos et al., 2013).

2. Intelligent Transportation Systems: Definitions, Concepts, Applications

The Intelligent Transportation Systems (ITS) are advanced applications of information and communication technologies aiming to provide innovative services related to various different modes of transportation and traffic management enabling users to be better informed, coordinated and make safer use of transport networks. These applications are applied in the field of road transport including vehicles and users, traffic and mobility management, various interfaces of transport modes improving the efficient of transport in related factors, such as traffic management, road transport, mobility etc.

The ITS is considered as the application of analysis, control, sensing and communication technologies for transportation improving efficiency, mobility and safety. These systems include several applications processing and sharing information improving traffic management, minimizing environmental impact, increasing benefit of transportation for commercial users and the public, promoting sustainable transportation development and enhancing productivity. The transportation infrastructure contains various tools of high technology and improvements in information systems, communication, sensors, controllers, mathematical methods and computational techniques used in intelligent transportation research and development (Ezell, 2010; Mandzuka, 2015). The ITS can apply information, data processing, communication and sensors technologies to various type vehicles, including cars, trucks, ships, aircraft, for transporting infrastructure and users increasing effectiveness, safety, efficiency, environmental performance.

In recent years the transportation systems have been greatly transformed by the rapid advance of information technology and transportation networks following the same development of many industries, education, health care, government services etc. (Tyagi et al., 2012; Al-Khateeb et al., 2008). The Intelligence Transportation Systems can combine different types of information and communication technologies for creating network of systems, protecting roads, managing traffic. These systems can improve transportation in the following ways:

(i) Improving traffic safety (heavy traffic, dangerous weather conditions, unsafe speeds)
(ii) Reducing infrastructure damage (overload of heavy vehicles, measuring type, size, weight of vehicles communicating data back to central servers)
(iii) Traffic control (smooth flow of vehicles through road networks, emergency vehicles)
(iv) Parking management (illegal parking, parking violation detections)
(v) Gathering traffic data (electronic traffic counters)

Extensive use of information and communication technologies has been recently applied in transportation infrastructure and in vehicles travelling on roads attributing intelligence transportation vehicles especially in cases that drivers identify any form of emergency acting on basis of proactive decision upon alternatives (Collier ad Weiland, 1994).

Current research on Intelligent Transportation Systems (ITS) is focused on the following areas:
(i) Traffic assessment and management: traffic info systems based on ad-hoc networks
(ii) In-vehicle and on-road safety management: assessing driving style via non-intrusive sensors monitoring the drivers (Bayly et al., 2009).
(iii) Emergency management: managing increased traffic caused by emergency situations or management of emergencies affecting the safety of vehicles route (Lexus Object Recognition web site, 2007)
(iv) Driver modelling methods: providing analysis of cognitive processes of drivers and predicting the impact of driver assistant systems on driver workload, safety and behaviour (Jurgensohn et al., 2009).
(v) ITS methods affecting environmental transportation effects: reducing emissions of vehicles by enhanced traffic and transportation management (Regan et al., 2006).
(vi) Development and deployment evolutionary ITS applications: sensor networks, network control techniques etc. (Bayly et al., 2009).

Transportation efficiency and safety can be maximized by assessing traffic conditions in real time, exploiting real time traffic information through network sensors and improving corresponding associated decision making algorithms. Another factor is that the traffic assessments and management systems should be decentralized allowing the communication to be done through internet, satellite and cellular systems. By using such autonomous manner, by exchanging information amongst
neighboring vehicles without central control and policy making entities the drivers are capable on deciding on proper directions to follow the indicated changes in short times. Finally, various intelligence facilities embedded in vehicles can greatly improve the overall safety status on global traffic conditions and vehicle/driver behavior (Dimitrakopoulos et al., 2013).

A proactive knowledge based intelligent transportation system and vehicular sensor networks has been recently presented capable to use collective information transferring knowledge, experience and proactive directives to drivers identifying potential dangers and contributing to integrated safety/emergency management in the framework of transportation quality. It is reported that the so called i-Drive system, can be extended by using neural network techniques and Bayesian networking concepts in order to increase its accuracy and reliability and to convert to an integrated all-in-one solution approach addressing safety factors, such as frontal collisions, dangerous turns, detection, and comfort factors, such as directions avoiding traffic congestions (Dimitrakopoulos et al., 2013).

3. On Decision Making Algorithm Operability

The wireless sensors decide on the process in vehicle data sets, i.e. aggregated data to be sent for processing, how often such data will be sent, while several sensor measurements are processed in hierarchical manner with special reasoning techniques yielding information about the vehicle/driver interactions at various abstraction levels. Note that the required communication time for reaching a decision is few microseconds.

The decision making algorithmic procedure includes several phases, such as
(i) Input: context acquisition, profiles, drivers’ priorities, several policies for performance, safety, reliability and stability of decisions etc.
(ii) Output: issuing
   ► directives/commands towards the vehicles driver,
   ► system algorithmic process: safety, performance, reliability, stability, vehicle behaviour: velocity, delays,
   ► knowledge and experience creation:
     keeping track of certain contextual situations,
     estimating possible dangerous situations,
     learning and improving certain predetermined specifications.

During the operation the system can perform initial searches in the classified databases checking whether similar situations have been encountered and how they have been tackled. In this case the algorithm does not executed and previous related decisions can be applied. This algorithm is running only when some changes occurred and so valuable time can be saved and the overall system complexity is reduced.

4. The Adaptive Algorithmic Process

The adaptive algorithm for the proactive knowledge intelligent transportation system based on vehicular sensor networks can be described in the following pseudoalgorithmic form. This adaptive algorithmic procedure includes three computational modules, namely
(i) module-1: IAC for information acquisition and classification
(ii) module-2: INP for normalization and processing and
(iii) module-3: OF for computation of objective functions and evaluation

The singular perturbation (sp) parameters \( \varepsilon_{IA} \), \( \varepsilon_{IN} \), \( \varepsilon_{D1} \), \( \varepsilon_{D2} \), \( \varepsilon_{D3} \) and uncertainty-factor parameter \( \varepsilon_{UF} \) can be used can be used for (near) optimization of the corresponding functions.

Algorithm ITS-VSN-1 \( (\varepsilon_{IA} \text{ IAC, IVVSN, } \varepsilon_{IN} \text{ INP, } \varepsilon_{D1} \text{ DF1, } \varepsilon_{D2} \text{ DF2, } \varepsilon_{D3} \text{ DF3, OF1, OF2, } \varepsilon_{UF} \text{ OF}) \)

**Purpose:** This algorithm facilitates the transportation quality for the proactive knowledge of intelligent transportation system based on vehicular sensor networks

**Input:** IAC information acquisition and classification, IVVSN input parameters from infrastructure, vehicles sensors, vehicle-to-vehicle and vehicle-to-vehicular sensor networks, INP input parameters about normalization and processing, DF1-DF2-DF3 danger factors, singular perturbation (sp) parameters \( \varepsilon_{IA} \), \( \varepsilon_{IN} \), \( \varepsilon_{D1} \), \( \varepsilon_{D2} \), \( \varepsilon_{D3} \) and uncertainty-factor parameter \( \varepsilon_{UF} \)

**Output:** Object Function OF1, Object Function OF2, total function OF

**Computational procedure:**
/phase-1: information acquisition and classification/
Step 0: read singular perturbation parameters \( \varepsilon_{IA} \), \( \varepsilon_{IN} \), \( \varepsilon_{D1} \), \( \varepsilon_{D2} \), \( \varepsilon_{D3} \) and uncertainty-factor parameter \( \varepsilon_{UF} \)
module-I \( \varepsilon_{IA} \) IAC (NVES, VVSN)
Step 1: define number of vehicles in range through the embedded sensors in vehicles (NVES)
Step 2: collect required information about input parameters from infrastructure, vehicles sensors,
vehicle-to-vehicle and vehicle-to-vehicular sensor networks (VVSN)
/check the input parameters which can be classified by using 5-point of Likert scale, e.g. fuel level: full, high, medium, low, marginal/
   Step 2.1: check driving style
   Step 2.2: check road type
   Step 2.3: check fuel level
   Step 2.4: check vehicle condition
   Step 2.5: check road condition
   Step 2.6: check congestion
   Step 2.7: check vehicle velocity

/phase-2: normalization and processing/
module-2 εΝP INP (IS, VS, LD, DF)
Step 3: collect required information about input parameters about normalization and processing
   Step 3.1: check infrastructure sensors (IS)
      Step 3.1.1: check road condition
      Step 3.1.2: check congestion level
      Step 3.1.3: check road type
   Step 3.2: check vehicle sensors (VS)
      Step 3.2.1: check vehicle velocity/acceleration
      Step 3.2.2: check the number of vehicles in range
      Step 3.2.3: check velocities/accelerations of vehicles in range
      Step 3.2.3.1: check the number of vehicles in range moving in the same direction (ahead)
      Step 3.2.3.2: check the number of vehicles in range moving in the same direction (behind)
      Step 3.2.3.3: check the number of vehicles in range moving in the opposite direction
   Step 3.3: check the level of danger arising from several combinations of related parameter values (LD)
   Step 3.4: compute the corresponding danger factors (DFi) for the final decision using the relationship:
   \[
   DFi = \sum k \left[ \frac{(vi - vj)}{(vi + vj)} \right],
   \]
   /where k is an acceleration (k=0)/deceleration (k=1) parameter and vi, vj are the velocities of vehicle i and vehicle j respectively/
/phase-3: computation of objective function and evaluation/
module-3 εOF OF (OF1, OF2)
/the output for a decision is based on these parameters with several actions-states, i.e. the
Intelligent Transportation Systems (ITS) contains the following states:
ITSS= (idle, warning, low importance alert-front, low importance alert-rear, high importance alert-front, high importance alert-rear)/
Step 4: compute the objective function OF as follows:
   Step 4.1: compute the objective function OF1 as follows:
   \[
   OF1 = \sum (w_i \cdot n_{vi}),
   \]
   /where n_{vi} are the normalized values of parameters i and w_i are weighed parameters/
   Step 4.2: compute the objective function OF2 as follows:
   \[
   OF2 = \varepsilon_{DFj} \cdot DFj / N_j, j=1,2,3
   \]
   /where DFj are the danger factors and N_j are the set of vehicles moving in the same direction (ahead-behind) and in the opposite direction/
   Step 4.3: compute the total objective function (OF) as follows:
   \[
   \varepsilon_{OF} OF = OF1 + OF2,
   \]
   /note that for several values of OFT the corresponding ITSS parameters can be obtained and notify the driver/
Step 5: consider the total objective function OFT and the overall safety levels recognizing a priori emergencies, improving the transportation quality.

The algorithm ITS-VSN-1 can be used for a proactive knowledge based intelligent transportation system acquiring collective information, transferring into knowledge and experience and issuing proactively significant directives to drivers for facilitating transportation. An efficient intelligence system operating on the basis of collection related information from vehicles and infrastructure objects through sensor networks with its software prototype implemented in Matlab has been recently presented (Dimitrakopoulos et al., 2013).

5. On the Functionality and Improvement of Intelligent Transportation Systems

Several related research efforts using modified inputs of functionality concerning context, personal and service profiles and policies have been recently presented showing how fast the proposed functionalities can affect decisions exploited by drivers during various emergency situations (Saatsakis and Demestichas, 2009; Gukeisen et al., 2007).

Different scenarios and simulations have been introduced with various danger levels and road conditions causing dangers and emergencies. These include the impact of road types and the impact of road conditions on drivers’ decisions. Different road type and velocity/acceleration cases can be
considered (highways, national, village roads) testing the response of driver for different levels of danger arising from there in low/high danger situations. Different road conditions can be also considered, i.e. good condition road and snowy/ slippery road, with high level of dangers.

These scenarios show that efficient algorithms provide important and helpful tools for the drivers regarding their a priori notification of potential forthcoming dangers by using fast and reliable decisions regarding the origin and intensity of dangers. The simulations assume that the road and type condition parameters are of quite high importance, while the parameters regarding other vehicles moving in the same direction are of very high importance.

6. Conclusion

An adaptive algorithmic procedure for a proactive knowledge based intelligent transportation system based on vehicular sensor networks has been presented. This algorithm operates by collecting information from certain vehicles and infrastructure objects through vehicular sensor networks by using intelligent processing, integrating knowledge and experience and issuing directives to drivers facilitating transportation quality. The efficient operability of this algorithm can be demonstrated by related simulations showing improvement in the transportation quality. Future research work will be directed for intelligent methods estimating parameters weights by using advanced neural networks and Bayesian networking techniques for improved intelligent transportation quality.

7. References

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