Scanning the Issue and Beyond: ITS With Complete Traffic Control

WELCOME to the second issue of our IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS under the new bimonthly schedule. Please check @IEEE-TITS (http://www.weibo.com/u/3967923931) in Weibo (an extended Chinese version of Twitter), https://www.facebook.com/IEEEITS on Facebook, and @IEEEITS (https://twitter.com/IEEEITS) on Twitter for any news regarding the IEEE Intelligent Transportation Systems Society (ITSS), IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, and IEEE *Intelligent Transportation Systems* magazine. These three sites are still under development, and your participation is extremely welcome.

Here, I do have an important news item for you: At the IEEE ITSS Executive Meeting held on March 1, 2014 at Nassau, Bahamas, a proposal was made and approved to explore the possibility of launching a new IEEE TRANSACTIONS ON INTELLIGENT VEHICLES in 2016. As you can imagine, this could be a significant development and impact for our society and our TRANSACTIONS, and I believe it will be good for the long-term benefit of our society and our professional community.

Finally, I would like to share my thought on extending traditional intersection traffic controllers from points to lines, to areas, and even to three-dimensional traffic-control systems.

SCANNING THE ISSUE

Support Vector Number Reduction: Survey and Experimental Evaluations

H. G. Jung and G. Kim

This paper is intended to help engineers using a support vector machine to apply support vector number reduction by providing a state-of-the-art survey and quantitatively comparing three implementations. In particular, it confirms that the support vector number of a pedestrian classifier can be reduced by more than 99.5% without any accuracy degradation using iterative preimage addition, which can be downloaded from the Internet.

ITS for Sustainable Mobility: A Survey on Applications and Impact-Assessment Tools

P. M. d'Orey and M. Ferreira

This paper presents how mobility players and enablers influence fuel consumption and pollutant emissions. It details how different intelligent transportation systems (ITS), ranging from eco-routing to intelligent intersection management, can lead to sustainable mobility by promoting more efficient vehicle usage and enhanced efficiency on road-network utilization. Results show that ITS has the potential to considerably reduce fuel consumption and pollutant emissions. Methods from both field operational tests and simulation-based evaluations are analyzed.

Will the Pedestrian Cross? A Study on Pedestrian Path Prediction

C. G. Keller and D. M. Gavrila

This paper studies pedestrian crossing behaviors using real stereo data obtained from a vehicle. Results indicate similar performance for the four approaches on walking motion, with near-linear dynamics. During stopping, however, the two newly proposed approaches, with nonlinear and/or higher-order models and augmented motion features, achieve a more accurate position prediction around the stopping event.

The Path Inference Filter: Model-Based Low-Latency Map Matching of Probe Vehicle Data

T. Hunter, P. Abbeel, and A. Bayen

The problem of reconstructing vehicle trajectories from sparse sequences of GPS points is addressed by introducing a new class of algorithms, which is called the path inference filter (PIF). An efficient procedure for automatically training PIF is presented and evaluated on a large taxi data set. The PIF also provides insights about driving patterns of drivers and has been deployed at an industrial scale and used to map fleets of data in San Francisco, CA, USA; Sacramento, CA, USA; Stockholm, Sweden; and Porto, Portugal.

Modular Design of Urban Traffic-Light Control Systems Based on Synchronized Timed Petri Nets

Y.-S. Huang, Y.-S. Weng, and M. Zhou

Timed Petri nets (TPNs) have been utilized as a visual formalism for the modeling of complex discrete event dynamic systems. Moreover, it is well known that a synchronized timed Petri net (STPN) allows us to present all of the concurrent states in complex TPN. Here a new methodology to design and analyze an urban traffic network control system by using STPN is proposed. The analysis of the control models is performed to demonstrate how the models enforce the lights' transitions by a reachability graph method.

Vehicle Reidentification With Self-Adaptive Time Windows for Real-Time Travel Time Estimation

J. Wang, N. Indra-Payoong, A. Sumalee, and S. Panwai

A vehicle reidentification (VRI) system with self-adaptive time windows to estimate the mean travel time is proposed. To capture real-time traffic dynamics, the interperiod adjusting is introduced to define an appropriate time window constraint for VRI. Simulation tests are carried out to evaluate the performance of the proposed VRI against the potential changes in

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traffic conditions, and results show that this method can perform well under uncertainty.

"No Free Lunch" Theorems Applied to the Calibration of Traffic Simulation Models

B. Ciuffo and V. Punzo

A general method for verifying the robustness of a calibration procedure is proposed, based on a test with synthetic data and a Kriging approximation of the simulation model. The methodology is tested, and the result indicates the clear dependence between calibration procedure performance and the specific case study conducted and ascertains the need for global solutions in simulation optimization with traffic models.

Evolving Bayesian Graph for Three-Dimensional Vehicle Model Building from Video

N. Ghosh and B. Bhanu

The process of 3-D model building of multiple vehicles by incrementally accumulating evidences in streaming traffic videos collected from a single static camera is addressed by proposing a structure-modifiable adaptive reason-building temporal Bayesian graph that self-modifies in a data-driven way for uncertainty propagation. Uncertainties are used as relative weights to fuse evidences and to compute overall reliability of the generated models. Results for different vehicles from several traffic videos, and two viewpoints, demonstrate the performance of the proposed method.

Design and Evaluation of Charging Station Scheduling Strategies for Electric Vehicles

J. Timpner and L. Wolf

The V-Charge project proposes a solution for charging autonomous electric vehicles in parking places and efficiently using scarce charging resources. Through intensive simulations, it shows that the V-Charge is able to efficiently handle realistic parking volume and performs well in fulfilling customer requirements, as well as offering the suitability of various scheduling strategies in different usage scenarios. For the simulation setup, real-world parking statistics obtained from Hamburg Airport and the city of Braunschweig, Germany, are used.

Agent-Based Simulation and Optimization of Urban Transit System

G. Zhang, H. Zhang, L. Li, and C. Dai

An artificial urban transit system (AUTS) is built to support a new day-to-day learning mechanism for describing passengers' route and departure-time-choice behaviors. By using AUTS to handle the lower level assignment problem, it is able to solve the upper level transit network design problem. Compared with other bilevel models, this approach better accommodates passengers' dynamic learning behavior and their heterogeneity. Computational experiments with AUTS have been conducted and revealed some interesting issues on the capacity of public transportation systems and passengers' heterogeneity.

Rear-View Vehicle Detection and Tracking by Combining Multiple Parts for Complex Urban Surveillance

B. Tian, Y. Li, B. Li, D. Wen, and Q. Yao

This paper proposes a rear-view vehicle-detection and tracking method based on multiple vehicle salient parts using a stationary camera. A vehicle is treated as an object composed of multiple salient parts that are localized using their distinctive color, texture, and region features and detected as graph nodes to construct a probabilistic graph using a Markov random field. The marginal posterior of each part is inferred using loopy belief propagation for final vehicle detections. Experiments show that this method can achieve real-time performance with an average vehicle detection rate of 95% and a tracking rate of 90%.

Estimating Speed Using a Side-Looking Single-Radar Vehicle Detector

S.-L. Jeng, W.-H. Chieng, and H.-P. Lu

This paper presents a side-looking single-beam microwave vehicle detector for estimating per-vehicle speed and length. The associated Fourier processing is based on the inverse synthetic aperture radar algorithm, which can extract the range and speed information of each vehicle using a single-beam frequency-modulated continuous-wave radar. The simulation and experimental results show accurate estimations of vehicle speed and length and excellent detection capability for small moving targets, such as bicycles and pedestrians.

Hybrid Communication Protocols and Control Algorithms for NextGen Aircraft Arrivals

P. Park, H. Khadilkar, H. Balakrishnan, and C. Tomlin

This paper presents a framework for managing arrivals at an airport using a hybrid centralized/distributed algorithm for communication and control, by combining centralized control in congested regions with distributed control in lower traffic density regions. The algorithm is evaluated through realistic simulations of operations around a major airport. The proposed strategy is shown to significantly improve air traffic control performance under various operating conditions, by adapting to the underlying communication, navigation, and surveillance systems.

Reversing the General One-Trailer System: Asymptotic Curvature Stabilization and Path Tracking

M. Werling, P. Reinisch, M. Heidingsfeld, and K. Gresser

This paper develops two feedback controllers to support a driver for backing up a trailer in various situations. Based on the kinematics of the general one-trailer system, an input/output-linearizing control law is derived, which asymptotically stabilizes a given curvature for the trailer and enables the driver to directly steer the trailer such that the trailer will automatically be prevented from jackknifing. In combination with a path-planning algorithm, this enables automated parallel parking. The complete system is implemented in a rapid prototyping environment and evaluated in real-world scenarios.

A Framework for Estimating Driver Decisions Near Intersections

V. Gadepally, A. Krishnamurthy, and Ü. Özgüner

A framework for estimating driver behavior at intersections is presented by modeling driver decisions as a discrete-state system and the vehicle dynamics as a continuous-state system. This paper describes an approach that encompasses the hybrid structure of vehicle–driver coupling and uses hidden Markov models to estimate driver behavior from filtered continuous observations. A comparison is made between the proposed framework, simple classifiers, and naturalistic driver estimation. Obtained results show promise for using the hybrid-state-system–hidden-Markov-model framework.

Modeling Mandatory Lane Changing Using Bayes Classifier and Decision Trees

Y. Hou, P. Edara, and C. Sun

A lane-changing assistance system that advises drivers of safe gaps for making mandatory lane changes at lane drops is developed. The best results were obtained when both Bayes and decision-tree classifiers were combined into a single classifier using a majority voting principle. The prediction accuracy was 94.3% for nonmerge events and 79.3% for merge events.

An Efficient Hardware Implementation of HOG Feature Extraction for Human Detection

P.-Y. Chen, C.-C. Huang, C.-Y. Lien, and Y.-H. Tsai

This paper presents a low-cost high-speed hardware implementation for histogram of oriented gradients (HOG) feature extraction. The simulation shows that the proposed circuit can achieve 167 MHz with 153-K gate counts by using Taiwan Semiconductor Manufaturing Company 0.13-μm technology. Compared with the previous hardware architectures for HOG feature extraction, the proposed circuit requires less hardware cost and achieves faster working speed.

Tire Radii Estimation Using a Marginalized Particle Filter

C. Lundquist, R. Karlsson, E. Özkan, and F. Gustafsson

Measurements of individual wheel speeds and absolute position from GPS are used for high-precision estimation of vehicle tire radii. The novelty lies in a Bayesian approach to estimate online parameters representing the process noise statistics using a marginalized particle filter. Field tests show that the absolute radius can be estimated with submillimeter accuracy. The approach is tested in accordance with the ECE R-64 regulation on a large data set and outperforms Kalman-filter-based methods when compared for accuracy and robustness.

Optimization of Multitrain Operations in a Subway System

S. Su, T. Tang, X. Li, and Z. Gao

This paper analyzes the hierarchy of energy-efficient train operation and proposes an integrated algorithm to generate the globally optimal operation schedule for a better energy-saving performance. Meeting the passenger demand, the integrated energy-efficient algorithm can simultaneously obtain the optimal timetable and driving strategy for trains, which realizes the combination of the high-level transportation management and the low-level train operation control. The simulation results based on the Beijing Yizhuang Subway Line illustrate that the integrated algorithm can achieve an average 24% energy reduction for one day.

Algebraic Connectivity Maximization for Air Transportation Networks

P. Wei, G. Spiers, and D. Sun

An experiment based on the real air transportation network is performed to show that algebraic connectivity is a fair measure for network robustness; the goal of this work is to maximize the algebraic connectivity. A new air transportation network model is formulated, and the corresponding algebraic connectivity optimization problem is addressed. The approximation algorithm is proposed for algebraic connectivity maximization of large networks with cluster decomposition. Simulations are performed for small-scale, large-scale, and directed-network problems.

Impact of Gate Assignment on Departure Metering

S. H. Kim and E. Feron

In order to simulate the airport departure process for departure metering and to solve a gate-conflict problem, a queuing model is introduced here. The model is calibrated and validated with actual data from LaGuardia Airport in New York, which is a large U.S. hub airport. It simulates the airport departure process with the current and a robust gate assignment to assess their impacts on departure metering. The results show that the robust gate assignment reduces the number of gate conflicts caused by departure metering.

Valuating Surface Surveillance Technology for Collaborative Multiple-Spot Control of Airport Departure Operations

P. Burgain, S. H. Kim, and E. Feron

This paper explores the environmental and safety benefits that improved surveillance technologies can bring in the context of gate- or spot-release strategies. It shows that improved surveillance technologies can yield a 4%–6% reduction of the average number of aircraft on the taxiway system during congested operations, therefore reducing emissions in addition to the savings currently observed, by implementing the threshold-based metering strategies under evaluation at Logan Airport in Boston and other busy airports. This work is illustrated by its application to the LaGuardia Airport in New York and the Seattle–Tacoma Airport.

A Macroscopic Forecasting Framework for Estimating Socioeconomic and Environmental Performance of Intelligent Transport Highways

B. W. Kolosz, S. M. Grant-Muller, and K. Djemame

This paper uses the intelligent transportation systems (ITS) performance-assessment framework EnvFUSION to perform dynamic forecasting of the performance for three key ITS technologies. A consequential lifecycle assessment is undertaken, which forecasts improvements that are in line with social acceptability, economic profitability, and major carbon reduction scenarios up to 2050 on one of the U.K.'s most congested highways. Results indicate that there will be a substantial increase in socioeconomic and emissions benefits.

Fault-Tolerant Adaptive Control of High-Speed Trains Under Traction/Braking Failures: A Virtual Parameter-Based Approach

Y. D. Song, Q. Song, and W.-C. Cai

This paper presents an automated train-control scheme for high-speed trains with combined longitudinal aerodynamics and tracking/braking dynamics, with special emphasis on reliable position and velocity tracking in the face of traction/braking failures. The controller is synthesized using a so-called virtual parameter-based backstepping adaptive control method, which exhibits several salient features. The effectiveness of the developed control scheme is authenticated via a formative mathematical analysis based on Lyapunov stability theory and is also validated via numerical simulations.

Bandwidth Synchronization Under Progression Time Uncertainty

J.-Q. Li

The MAXBAND model has an infinite number of optimal solutions. Different optimal solutions may have different sensitivity to progression time uncertainty. The models are first solved with perturbation controlled by a parameter to generate a number of optimal or near-optimal plans. The Monte Carlo method is then applied to simulate random progression time, evaluate the generated plans, and rank them by reliability. Extensive microscopic traffic simulation is conducted to evaluate delays and stops for certain optimal plans.

Rail Component Detection, Optimization, and Assessment for Automatic Rail Track Inspection

Y. Li, Ying, H. Trinh, N. Haas, C. Otto, and S. Pankanti

A real-time automatic vision-based rail inspection system is proposed to detect key rail components. A novel global optimization framework is used to process inputs from cameras, GPS, and distance measurement instrument for improving detection performance. Special effort is made to detect anchor exceptions. Tests have indicated average 94.67% precision and 93% recall rates on detecting three key rail components and a 100% detection rate for compliance-level anchor exception with three false positives per hour.

Compact Configuration of Aircraft Flows at Intersections

S. Huang, E. Feron, G. Reed, and Z.-H. Mao

The goal here is to achieve higher capacity of the airspace, allowing more aircrafts to fly safely through a fixed region. Intersections of aircraft flows are considered as basic building blocks for air traffic networks constructed through optimal arrangements of intersections whose conflict zones do not overlap. The relationship between the size of a conflict zone and the intersection angle of the two flows is derived and is used to guide the choice of the most compact configuration for intersecting aircraft flows.

Negative Binomial Additive Models for Short-Term Traffic Flow Forecasting in Urban Areas

Y.-A. Daraghmi, C.-W. Yi, and T.-C. Chiang

This paper proposes a novel spatiotemporal multivariate forecasting model that is based on the negative binomial additive models. Real-world data collected from Taipei City, Taiwan, are used for evaluation and comparison with other forecasting models. The results indicate that the proposed model is an accurate and efficient approach in forecasting traffic flow in an urban context, in which flow is overdispersed, autocorrelated, and influenced by upstream and downstream roads and the daily seasonal patterns.

Spatiotemporal Patterns in Large-Scale Traffic Speed Prediction

M. T. Asif, J. Dauwels, C. Y. Goh, A. Oran, E. Fathi, M. Xu, M. M. Dhanya, N. Mitrovic, and P. Jaillet

This paper proposes unsupervised learning methods, such as k-means clustering, principal component analysis, and self-organizing maps, to mine spatial and temporal performance trends at both the network level and for individual links. It predicts a large interconnected road network, for multiple prediction horizons, with a support vector regression (SVR)-based algorithm. It shows the effectiveness of the proposed methods by applying them to the prediction data of SVR.

A Macroscopic Signal Optimization Model for Arterials Under Heavy Mixed Traffic Flows

Y.-Y. Chen and G.-L. Chang

This paper presents a generalized signal optimization model for arterials experiencing multiclass traffic flows based on a macroscopic simulation concept. The efficiency of the proposed model has been compared with the benchmark program TRANSYT-7F under both passenger flows only and multiclass traffic scenarios from modest to saturated traffic conditions. Extensive numerical results under various traffic conditions have indicated that this may offer a new signal design for many arterials in congested downtowns or megacities in developing countries where transit vehicles constitute a major portion of traffic flows.

Continuous Head Movement Estimator for Driver Assistance: Issues, Algorithms, and On-Road Evaluations

A. Tawari, S. Martin, and M. Trivedi

This paper presents a distributed camera framework for head movement analysis, with an emphasis on the ability to operate robustly and continuously even during large head movements. It tracks facial features and analyzes their geometric configuration to estimate the head pose using a 3-D model. For experimental evaluations, it has collected a novel head pose data set from naturalistic on-road driving in urban streets and freeways, with particular emphasis on events inducing spatially large head movements.

A Practical Roadside Camera Calibration Method Based on Least Squares Optimization

Y. Zheng and S. Peng

This paper proposes a practical and accurate method for calibrating roadside cameras used in traffic surveillance systems. Compared with the existing calibration methods, this method is suitable for more traffic scenes and is able to accurately determine more camera parameters including the principal point. For more accurate calibration, a dynamic calibration method to correct camera parameters is proposed. The experimental results on synthetic data and real traffic images demonstrate the accuracy, robustness, and practicability of the proposed calibration method.

Web-Based Traffic Sentiment Analysis: Methods and Applications

J. Cao, K. Zeng, H. Wang, J. Cheng, F. Qiao, D. Wen, and Y. Gao

The traffic sentiment analysis is proposed as a new tool to provide new perspectives for intelligent transportation systems. Methods and models in traffic sentiment analysis are discussed, and pros and cons of rule- and learning-based approaches are analyzed based on Web data. The rule-based approach is used for architectural design, the process construction, and online data collection. Two case studies regarding the "yellow light rule" and "fuel price" in China are conducted.

Controller Synthesis for String Stability of Vehicle Platoons

J. Ploeg, D. Shukla, N. van de Wouw, and H. Nijmeijer

A controller design method is developed that allows for explicit inclusion of the string stability requirement in the

controller synthesis specifications for vehicle platoons. The potential of this method is illustrated by its application to the design of controllers for cooperative adaptive cruise control for a one- and a two-vehicle look-ahead communication topology. The results are experimentally validated using a platoon of three passenger vehicles, illustrating the practical feasibility of the proposed method.

Development of a Control Strategy of Variable Speed Limits to Reduce Rear-End Collision Risks Near Freeway Recurrent Bottlenecks

Z. Li, P. Liu, W. Wang, and C. Xu

This study is to develop a control strategy of variable speed limits (VSL) to reduce the rear-end collision risks near freeway recurrent bottlenecks. The effects of the VSL control strategy are evaluated using the cell-transmission model. The genetic algorithm is used for optimizing critical control factors. Results of comparative analysis suggest that the proposed strategy has outperformed other strategies in reducing the rear-end collision risks near freeway recurrent bottlenecks: 69.84% and 81.81% for the high- and moderate-demand scenarios, respectively.

Smart Driving of a Vehicle Using Model Predictive Control for Improving Traffic Flow

M. A. S. Kamal, J.-I. Imura, T. Hayakawa, A. Ohata, and K. Aihara

This paper presents a vehicle driving system in a model predictive control framework that effectively improves a traffic flow. The vehicle driving system regulates a safe intervehicle distance under the bounded driving torque condition by predicting the preceding traffic. It also focuses on alleviating the effect of braking on the vehicles following behind, which helps jamming waves attenuate in the traffic. The proposed vehicle driving system has been evaluated through numerical simulation in dense traffic.

Analysis of GNSS Performance Index Using Feature Points of Sky-View Image

W. Hong, K. Cho, E. Lee, S. Im, and M. Heo

When the sky-view factor (SVF) is used to predict global navigation satellite system (GNSS) positioning, it is easily adopted as a performance index. However, when a conventional SVF is used in a land transport environment, the predicted value for GNSS positioning is often not consistent with the actual positioning error, but when sky-view-based dilution of precision (SVDOP) is applied, it was substantially close to the actual positioning error. Here, SVDOP is calculated with real GPS data, and its usefulness is validated.

Stochastic Park-and-Charge Balancing for Fully Electric and Plug-in Hybrid Vehicles

F. Häusler, E. Crisostomi, A. Schlote, I. Radusch, and R. Shorten

This paper tries to balance charging demand across a network of charging stations, with the objective to reduce the potential for excessively long queues that develop at some charging stations while other charging stations are underutilized. A stochastic balancing algorithm is presented to achieve these goals. A further feature of this algorithm is that it is fully decentralized and facilitates a plug-and-play type of behavior. By using this system, charging stations can join and leave the network without any changes to, or communication with, a centralized infrastructure.

A Bibliometric Analysis of the Intelligent Transportation Systems Research Based on Science Mapping

M. J. Cobo, F. Chiclana, A. Collop, J. de Oña, and E. Herrera-Viedma

This paper highlights the conceptual structure of the intelligent transportation systems (ITS) research field from 1992 to 2011. An automatic approach based on coword analysis for detecting and visualizing the hidden themes and their evolution across a consecutive span of years is applied. The results allow us to identify the topics or themes that have been studied by the ITS community, have reached the biggest impact, and are the possible future trends.

ITS With Complete Traffic Control

In the past few years, I have often chug through the Beijing metropolitan area at an average of around 10 to 15 mi/h, which is slower than in most other major cities around the world. I still remember that one day in the spring of 2012: it took me exactly 2 h to drive a distance that normally would take less than 20 min to complete, and I missed my appointment. While sitting in my car on congested roads or at crowd intersections, I often recalled a project I had for my 1999 class "SIE 658: Advanced Topics in Robotics and Automation," which was about the total and complete traffic regulation for achieving zero fatalities by automatically controlling each individual vehicle using dual GPS in a transportation network. The project was called "Future Traffic Control without Traffic Lights," a little futuristic before Google's autonomous vehicles take over our roads.

Now, I think we can achieve a "soft" version of such total and complete traffic control by integrating traditional intersection traffic controller, computer vision, cell phones, variable message systems (VMS), and new connected vehicular technology. In Tucson, Arizona, a city I have lived and worked in for over 20 years, many automated speed camera systems have been installed among selected sites for the purpose of decreasing speeding violations and reducing collisions. However, I believe this technology, combined with VMS and in-vehicle warning or display devices, can be used to develop *in situ* segment traffic controllers and regional traffic controllers: that is, in addition to safety considerations, using cameras to identify vehicles, their speeds, and their moving behaviors for the purpose of traffic control, monitoring, and regulating by laws. In this way, we can plan and manage the speed of vehicles and their driving behaviors along a segment of a road or among a region of a road network, just like we can control the traffic flow at road intersections through traffic light controllers. Geometrically, this is a generalization of intersection traffic controllers as point control to camera-based segment or regional traffic controllers as line or area control. I believe this extension could make our traffic networks more effective and less dangerous.

The complete or total traffic control provides a realistic mechanism for rapid implementation of some new and exciting methods and techniques in communication and control for traffic management, especially the concept from emerging new network technology, so-called software-defined

networking (SDN) and named data networks (NDN), as well as the ACP-based parallel control and management of complex systems that I introduced a decade ago. In SDN, network administrators are able to manage network services through abstraction or virtualization of lower level communication functionality by decoupling the system that makes decisions about where traffic is sent (the control plane) from the underlying systems that forward traffic to the selected destination (the data plane). As claimed by the Open Networking Foundation's white paper, "Software-Defined Networking: The New Norm for Networks," through such decoupling enterprises carriers gain unprecedented programmability, automation, and network control, enabling them to build highly scalable, flexible networks that readily adapt to changing business needs. I believe the idea of complete traffic control provides the basis for the concept of software-defined traffic networking (SDTN), which is a direct implementation of artificial transportation systems in my ACP approach. This combination may enable traffic network users or customers to obtain similar benefits or even more than those offered by SDN for communication. As a matter of fact, SDN provides only part of the AC functionality and no steps in P are involved so far, which could lead to a closed-loop network management for better performance, as described in the ACP-based parallel systems approach.

Hopefully complete traffic control and software-defined traffic networking, along with parallel traffic management, will become the new norm for traffic operations.

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