New Environment CREPE for transportation Control and its Effectiveness

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Abstract-**This paper discusses the control scheme for vehicle control for a future integrated transportation system forming a type of new generation of Intelligent Transportation System-ITS. The approach generally is focuses on the mechanisms for how to detect or estimate incidents on roads and to then communicate the information to each vehicle. The individual vehicular data is collected by using the Global Positioning System - GPS and the mobile phone network by means of a device equipped in each vehicle. For the purpose of this paper, the device will be referred to as "Reporting Equipment for current geographic Position" or REP. In the case where every vehicle within the transportation network is equipped with a REP is referred to as "Comprehensive REP Environment" or CREPE. With real-time information, the system can dynamically control the real world traffic and also predict road's incidents of the near future. To achieve those functions, a multi-cycles-micro simulation system is discussed with the data structure and control algorithms.**

Index Terms—**Micro simulation, integrated transportation system, generator, ITS, dynamic traffic control**.

1. INTRODUCTION

Dynamic traffic control is considered as one of essential requirements in the Intelligent Transportation System (ITS) to control traffic of vehicles. The authors proposed an Integrated Transportation System [1, 2, 3] for future transportation control which integrates not only various types of vehicles, but also facilities, environment and activities related to transportation. It provides en-route vehicular navigation information to drivers and the appropriate control strategies to control traffic efficiently by means of real-time information reported from the proposed new type of device which will be referred to as "Reporting Equipment for current geographic position" (REP) equipped in each vehicle. At the core of the REP is GPS which provides position, speed and direction information, and the mobile phone network which provides device level communications. The REP terminal uses the information from the mobile phone network to allow the Control Center to provide information/instructions to the individual drivers.

REP is currently not available but its development is generally regarded as trivial; GPS, mobile phone and small form-factor/single-board computers are commonplace and relatively inexpensive. It is expected that if each vehicle is equipped with a REP and special network for REP is established, then vehicle flow could be improved, especially in unexpected cases such as accidents, natural disasters, fires or terror attacks. The environment in which all vehicles are equipped with a REP is referred to as the Comprehensive REP Environment or CREPE.

This paper proposes a micro-simulation-control system for multi-cycles detecting and estimating functionality to dynamically control vehicles in CREPE and predict the future incidents on road, and compare the various components with regard to the benefit of ITS for functionality planning [4], scenario generation [5], control optimization [6], and congestion prediction/traffic behavior at the operational level with different technologies [7, 8, 9, 14, 15, 16]. It uses various sensors such as speed sensor [10], vehicle counters [11], video cameras [12], and remote sensing from satellites [13]. Most importantly these are currently available technologies which are under continual improvement. The cost of implementing such a system, even with such inexpensive individual components, is purely dependent on the number of sensors installed; although it is viewed that this approach may be less expensive than what is being proposed, however it does not provide the level of improvement as that being proposed.

2. MOTIVATION

The prime purpose of ITS is to improve vehicle safety, and reduce management costs of environmental by improving vehicles control using IT. A large number of services have been deployed such as safety driving assistance, provision of in-vehicle services and information, vehicle and road management, and distribution systems for traffic data.

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The first generation of ITS is in-car navigation system using VCD/ DVD and GPS. Due the delay in updating road information, this system cannot provide real time information for drivers. In the case of new road construction or change of traffic regulations, this system cannot be able to inform it to drivers. Thus, this system is in-efficient for searching route.

In Japan, a consortium consisting of the Tokyo Metropolitan Police Department, the Ministry of Posts and Telecommunications, and the Ministry of Construction, formed to offer real-time traffic data; the system developed is known as VICS, which stands for Vehicle Information and Communication System [8], and it was launched in 1996 and can be considered as a 2nd generation of ITS. VICS can assist drivers to navigate by providing them with dynamic information. The VICS center first obtains information on traffic and road closures in real-time from the Japan Road Traffic Information Center which collects traffic data from others organizations such as local police departments or traffic control centers run by highway administrators. This kind of information is then analyzed and passed to drivers. In this way, VICS only provides traffic information to drivers and this information is collected from the others within the transport network. Thus, the natural latency associated with VICS can be considered significant due to the issue of information process delay and dissemination which requires drivers to download to use VICS's data. Furthermore, the traffic data from VICS is collected from fix-points sensors and VICS is deployed either in the central city or at critical junctions so VICS cannot process traffic conditions at all network locations.

3rd generation ITS solutions includes pre-crash accident avoiding systems such as AHS (Advanced Cruise-Assist Highway System) [9]. AHS attempts to prevent accidents before they happen by giving drivers real-time information on accidents and traffic congestion ahead. It uses sensors and road-to-vehicle communications to provide this information. Every car using AHS needs to be equipped with an in-vehicle sensor in order to communicate with the control center. However such devices are very expensive, so, AHS is currently only supported on highways, hence limiting its usefulness and coverage.

In order to improve traffic network systems and to co-ordinate the network of moving units, and integrate various kinds of transportation systems, Vogiatzis, Ikeda et al proposed an Integrated Transportation System – IMAGINATION [1, 2, 3] that takes into account all aspects of a transportation management system, using artificial intelligence, data streaming management systems, and GPS. The system is decentralized, stable and highly automated. IMAGINATION is a new type of integrated traffic management/ traffic micro-simulation system, in which each vehicle in the network is "connected" to IMAGINATION, thus there is no longer a need for the traffic signaling system to be interested in movement of vehicles between intersections.

3. IMAGINATION AND CREPE

3.1. CREPE assumption

The Comprehensive REP Environment is an environment in which all vehicles are equipped with a REP terminal. Since IMAGINATION (Integrated Multi Nodal Traffic Network system) [1] collects real-time traffic data from each REP terminal to construct and validate traffic control algorithms, it can efficiently control traffic and navigate each vehicle.

Currently there are many control systems implemented by different control technologies some of which include in-vehicle navigation; not all vehicles use this technology. However in spite of this, these systems still can operate with this limited capability. With an assumption whereby some

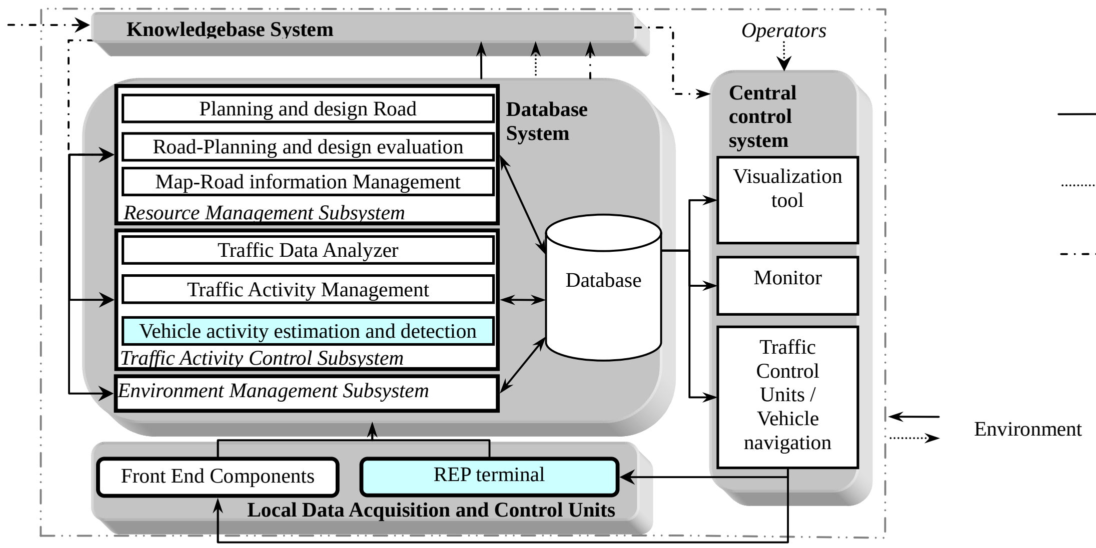

Figure 1. The configuration of IMAGINATION supported in CREPE

vehicles are equipped with a REP terminal as partial CREPE, IMAGINATION still can give efficient services such as navigation or estimation of congestion level by micro-simulation. Thus, IMAGINATION can simulate the traffic flow to evaluate its control algorithms; based on the collected data from partial REP terminals, it can estimate incidents on road and then deliver the information to in-network drivers or the traffic control centers. Naturally, it is expected that the more vehicles are equipped with a REP terminal the better the system can control vehicular movement. From this assumption, the following sections forms a configuration of IMAGINATION operated in CREPE.

3.2. IMAGINATION system configuration

Figure 1 indicates three layers of the system: local units in the bottom layer, individual and Statistical Data Systems (DBS) in the middle layer and Knowledgebase System (KS) in the top layer and an independent Central Control system (CCs) for some specified purposes.

The lowest layer manages specific controllers in locations of intersection, acquires data from those locations and controls the environment. Data is acquired by a local unit called front-end components; data is then transmitted to the data management system or related to control centers. Some data is used specifically for the control of individual locations whereas other data is locally summarized and then transmitted to the middle layer. Besides information collected from the front-end components, the REP terminal provides functionality for reporting and receiving information between the vehicle and the control center.

The DBS in the middle layer also manages data from individual controller and system-wide data for the purpose of resource management, analysis and transport facilities planning. The data in the middle layer are used for establishing new knowledge rules, supporting activities of managing transport office, registration of vehicles, the administrating of roads, etc.

In the top layer, KS manages the control/behavioral rules associated with the environment such as intersections, facilities and appropriate rules for conditions such as accident wardens, traffic congestion etc.

Finally, control centers are established for specific purposes such as a fire control center, highway monitoring center, road traffic monitoring etc. Each control center connects to the related local units to get appropriate data for its control mechanism.

3.3. New functions of IMAGINATION

To have high accuracy in traffic control, such as detecting or estimating incidents on roads, and efficiently navigating vehicles, a prime function of IMAGINATION is data collection. IMAGINATION introduced the notion of collecting data system using generic intelligent front-end components and a new type of intelligent mobile equipment installed in each vehicle. This new type of device uses GPS and mobile phone network (REP terminal). Thus, it is easy to deploy by using GPS, a mobile phone or a computer to make a connection between a REP terminal and a local control center. By this way, IMAGINATION can receive the traffic information in real-time by collecting current road and vehicle’s condition directly from REPs. Report information can be divided into two types. *Startup information*: including Vehicle/driver ID, current position by GPS, speed, destination of vehicle and report time. This type of information is reported only once when driver logs in to IMAGINATION. The second type of report is *Update information*: including Vehicle/ driver ID, current position by GPS, speed, direction of vehicle and report time. This type of information is sent frequently based on predetermined criteria. After collecting data, the system analyses the information to calculate the current situation of each vehicle and in return provides the right control operation for traffic.

IMAGINATION also generates data for road planning, incident management, etc; this kind of data is very important in order to predict near future traffic conditions.

Environmental data is also necessary; this includes map information, road information and crossing information. It is important to note that with such information the system can simulate also impact of transport such as fuel consumption, vehicle emissions/pollutants, travel times, etc, so the system can therefore also analyze transportation cost for each driver’s behavior, for example. The system can simulate the change of roads based on the requirements of traffic planners and analysts or to assist in the planning for new roads to improve traffic flow.

IMAGINATION uses real time traffic data, generated data and environment information to detect and estimate incidents on road which can be done by the micro-simulation subsystem. The simulation system allows for the simulation of activities control and management; this includes all activities in road, such as the vehicle movements or driver behaviors. Thus, the system should recognize the behavior of each driver, not only can detect congestion of each road but also to provide personalized route navigation for each vehicle, especially in emergencies and the case the status of the road changes dynamically. That information is used as input to the micro simulation subsystem, is real data from the traffic network itself. In this way, the simulation can validate the traffic control algorithms more effectively.

To control traffic flow, the system has to establish control algorithms. After it has received information from a vehicle, the system analyzes and gives personalized instructions to each driver/ vehicle based on an algorithm. In fact, the traffic control algorithms can not be proved without being evaluated; in order to analyze the performance of system, the improvement in efficiency, safety and operational productivity and so on. This type of evaluation is performed by the IMAGINATION micro-simulation system. This allows the system to control traffic dynamically and improve structure of road. A positive result from data analysis is a necessary requirement before applying the control algorithms to real world traffic.

The system can provide visualization; after data simulation, the system can visualize the current status of roads or predict possible incidents in the network. The visualization function includes static reports, such as number of vehicles on roads, saturation, level of service, etc; dynamic monitoring (dynamic vehicle navigation, also road planning…). Furthermore, the proposed simulation system also has an animation program that can help operator understand the traffic status. Currently, it can show video images from cameras, however just a small part of traffic can be displayed. In the simulation system, we can provide a three dimensional view of whole current traffic system at any time, any part or any direction. The operators can see the movement of individual vehicle and also the condition of traffic flow, etc.

To support these functions, the IMAGINATION system is configured as in figure 1, in which, the Vehicle activity estimation and detection subsystem is operated as a micro-simulation and is used for dynamic traffic control by using real-time traffic information collected from Front-end components and REP terminals.

4. IMAGINATION MICRO-SIMULATION

This section forms discussions for implementation of the real time micro-simulation. To achieve the simulation in real time, we have to use high speed computer to support parallel processing with efficient data structure and good algorithms.

4.1. Data structure of micro-simulation

Micro-simulation located in the Database System in the second layer. Its database is gathered from the main database of the Database System. We design the same data structure both input and output data of the simulation. Figure 2 shows basic data structure of micro-simulation, in which, we separate data into three types. One is permanent data items such as infrastructure data (roads, facilities, etc). The second one is temporal data items such as activities of vehicle on roads or the simulation of number of vehicle running on roads. The third one is permanent data items which specifically used for simulation; this kind of data is generated by the generator. Thus, to simulate CREPE, generated data plays an important role not only to build the input models for micro-simulation such as models for roads, vehicles, traffic rules, incidents, etc, but also to generate the results such as road structure which use to analyze the estimation of road conditions.

To achieve the classification of data, we added some simulation parts to the main database of the system. For example, in the road data, we can include the data relating to existing roads, and add the planning data for the simulation. That means, at the record level, we can extend the data in different way such as add tables, add attributes or add records. We call these methods *three dimensional extensions*. In addition to the *adding* method, we can *select* some attributes, table or records to use in the micro-simulation.

4.2. Generators

Transportation simulation needs to deal with the real world scenarios to be useful, thus, the system has to understand real world configuration; in this case, that is the road network information. Beside real world information collected, the *generated data* is one core input of the IMAGINATION micro-simulation. As shown in figure 3,

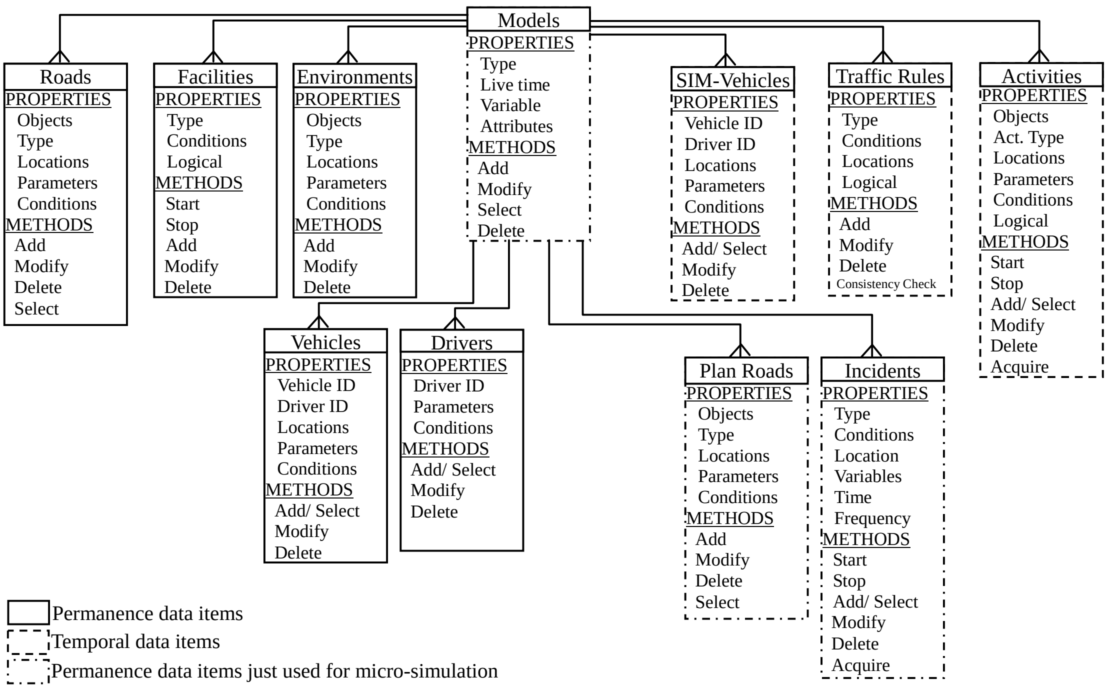

Figure 2. Basic data structure of micro-simulation models

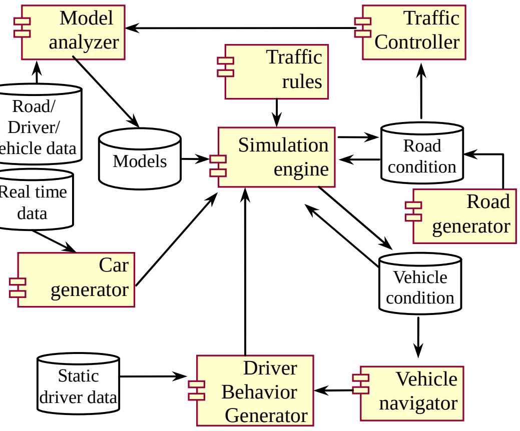

Figure 3. Micro-simulation system components

IMAGINATION can generate activities of vehicles, driver behaviors, road structure, or others such as fire or disasters, etc.

The *real-time traffic data* is collected from number of fix point's detectors such as sensors or cameras and so on, or from REP terminals in each vehicle in the future deployment. The car generator plays an important role to generate the current status of each vehicle in advance. In this case, although the REP terminals are just deployed partially, our system still can operate efficiently by the generated information.

Driver and vehicle interaction has been a subject of importance for many simulation tools. The interaction between the vehicle and unpredictable human behavior is very complex. However, while driver behavior is not easily predicted, it can be estimated by using models or by collecting the historical data of drivers. Thus, the historical data of each driver such as route choice strategy is captured and managed time by time. In this system, we use the Driver Behavior Generator to generate driver behavior as the input into the simulation.

Simulation output includes road condition (congestion level, traffic volume), and vehicle condition (estimation of vehicle location, direction, average speed, etc). Such kind of estimated information is useful for the control the real world traffic system or navigation system. In our system, that data will also be re-input to the simulation system to make *dynamic simulation cycles* that will be explained in the last section. To analyze road condition information before re-input to the simulation, the Road Generator is used. It not only generates road structure, but also road regulations, such kind of information will be used to adjust road condition as one input for the next cycle of the simulation.

By the generators of the simulation system, the IMAGINATION can provide "any time and any where" traffic control.

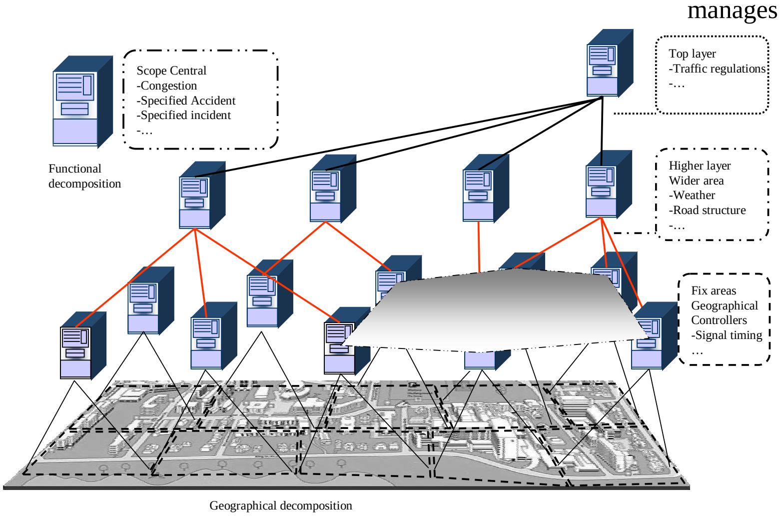

Figure 4: Deployment a decentralized system of simulation CPU

4.3. Hierarchical composition structure

There are number of types of data to be generated, but the important thing is how to divide and share such kind of data with each component. For each component of the generator, the computation associated with the generator is performed with parallel processing techniques; each computer deals with local data and treat many cycles of estimation process. There is a *hierarchical of composition* to share data among CPUs as described in figure 4. The policy to separate information to each CPU is as following. Some information should be managed in top layer, such as weather or environment data. Some information (roads, etc) should be managed in the middle layer as share data items. Finally, some information such as current position of car or incidents is of importance only in local areas, and the local areas give that information to each vehicle. That means we assign data to different places call area composition and locality divide. For example, in each table we not only assign entry the table to each area but also horizontally or vertically divide by attributes or records and give to each local CPU. After divided data locally, each local CPU treats many cycles of estimation process. The generator generates the moving of each vehicle. The local CPU accepts this car in its area and manages it. When a car is moving to the intersection of a new area, a site transformation performed. Each CPU not only has independent processing but also shares information to each other. Thus, the generators assist the micro-simulation process by acting as a real time micro-simulation system and it can cover very wide areas.

By the hierarchical of composition, the CREPE is deployed as a decentralized system shown in figure 4. We design to apply functional decomposition for the scope central which manages special accidents, special incidents of traffic congestion on roads. Number of simulation CPUs are divided by geographical decomposition, including the local areas CPUs, higher layer CPUs and top layer CPUs.

4.4. Cycles for dynamic traffic control

After data is collected and analyzed, the system constructs models and then executes the simulation and finally reports the results. Those processes form one cycle of simulation.

The first thing to make the simulation can work dynamically, with functions of detecting and estimating incidents on roads, is simulation speed. After estimating the future condition of a vehicle, such as speed or destination, the system evaluates those results by comparison with the real time information collected from REP terminals or fix points sensors. In fact, the IMAGINATION simulation system has to perform its simulation functionality at significantly higher speeds simulation than the currently available real time simulation system, in fact we call this short time simulation and this refers to the fact that the simulation must perform its computations at a type of *hyper* speed. In the case of detecting and estimating the future conditions, we have to accelerate the system ten times or hundred times to ensure that the system can calculate quickly, and so ensure that the decisions being made are not rendered obsolete by changing network events. Thus, the simulation and real-time reporting system work in parallel. That means the system monitors the real world continuously. We can apply high speed simulation, then, to control the real world.

In previous discussion, one of inputs of the simulation system is traffic models, including road model, frequency of vehicle model, etc. During simulation, we can evaluate the simulation results time by time to modify the input models to make the simulation system work more correctly. After this, the system re-estimates again and continues to collect real-time information. This is manifest in cycles of the dynamic-changed-input-models processes, while the traditional simulation is usually start at once gets the results and finish.

After each cycle of simulation, the system can estimate or detect the condition of traffic, such as the congestion level of one crossing, as an example; in the case that traffic in a given link congested heavily, the system will give that information to each car or some alarm in electric board or via some announcement; that means we can make the operations, depending of simulation results, called dynamic operations. Beside the dynamic operations, the system should evaluate operation results, which can be done by the multi-cycles processes. In some abnormal cases, we have to stop a vehicle or change the control of the signals, that operation will impact the other operations. Those dynamic processes can be evaluated one by one, and can be revised. That means we can estimate those abnormal cases to find the suitable operation to avoid such kind of serious things, then watch continuously and re-evaluate it again. Thus, the system watches some parameters, such as the average speed of the car or the congestion level of some specific points, and also the traffic volume of each place, then used the information collected to calculate some parameters such as volume of each area to compare with the established one.

5. CONCLUSION

In this paper, we discussed the integrated transportation system, and specifically micro- simulation system for dynamic traffic control operating in CREPE. This is new approach of using the real-time information of REP terminal and generated data for detecting and estimating incidents on roads in the near future by generators. The multi-cycles simulation system which done by power computers using that real-time information is running in parallel with the collecting system can predict near future road conditions. Simulation components with data structure to manage and analyze traffic information are being deployed. Thus, it opens up a new way for real-time monitoring urban traffic and its implementation forms the next phase of our work.

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