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MODEL OF AUTOMOBILE ARTERIAL TRAFFIC BY GPS-SAMPLE ELECTRODE DATA

In this article the model of arterial traffic on the basis of GPS-sample electrode sparse data is developed. Traffic monitoring system are mainly limited with highways and lean on the state or private data channels from specialized explorative infrastructure, which often includes loop detectors, radars, video cameras. GPS systems exists already for several decades, however only during the latest decade devices which are able to present high-precision tracking information at relatively low expenses. This development led to the usage of cheap GPS-detecting devices, located in the vehicle for gathering of the information about the traffic. The main advantage of GPS-sample electrode is that the terms of flow can be changed everywhere, where the sensors get. Arterial network represents additional tasks of modeling and estimation, because flow physics, which regulates them is more difficult because of the traffic lights (usually with unknown cycles), intersections, stop signs and parallel queues. This fact means that approaches to the regression can potentially be very successful at the traffic conditions estimation. Obtained results in the work promotes the growth of smartphone industry with GPS support, as well as another sources for providing information about the vehicle traffic in the mode of real time to the drivers and transit agencies.Proposed statistical model is based on the achievements in several areas, including the theory of flow.

Keywords: *arterial traffic, GPS, traffic monitoring, rout, regression model.*

Introduction

Systems of traffic information play important role in the world, because many people rely on the net of automobile vehicle for their the most important everyday functions [1–3]. Important step in extenuation of the traffic congestion is creation of the traffic monitoring systems creation consequences in real time. This article proposes common architecture system for processing of the data on traffic and spreading of accurate or up-to date information about the traffic through the Internet.

Traffic model with special attention to the estimate of arterial traffic on sparsed GPS-sample electrode data is developed. Arterial (also is known as secondary network) are main streets of the city (not high roads), which provide trips inside and between the cities. Sample electrode data concerns to location management and speed, provided by the subset of vehicle, travelling on the road network. This work expands availability of mobile devices (i.e. mobile phones) with such sensors as GPS, which can provide detailed information about the traffic terms, tested by the driver who carrying the device. The aim of work is to ultimately provide accurate, punctual estimations and prognosis of the flow terms for everybody.

GPS-sample electrode data promises to be the most spread source of data on the traffic for long years, because transit agencies reduce their investments into traditional fixed location detection infrastructure [4–6].

1. Visual routs (Virtual Trip Lines, VTL)

VTL composes the basis of the system of “joint participation”, which allows separate users to download an application on his smartphone with GPS support, which sends the data on the traffic, as well as obtains information about the traffic and warnings. VTL is a virtual line, drawn on the road. The main idea is that the phone tracks passed every few seconds and loads VTL list in common region where the phone is located. When the phone crosses one of the VTL-server, it sends the update for central VTL-server, detecting the speed and time of crossing, as well as transmission time of previous VTL, which was crossed with it. Accuracy of the data, generating with frequent GPS-sample is very different from GPS-chip type in the telephone and can be very good in some cases and very ban in the others. Usually accuracy is enough for estimation of road traffic with appropriate filtration [7]. For arteries the speed measurements are not reliable, that is why time measurements in the routs is the only available data which is suitable for estimation of arterial traffic. Transit time measurements are also should be controlled.

Nokia [8] initially has developed the first system of data selection about the flow on the basis of VTL in 2007. This system was firstly tested in the frames of Mobile Century experiment in February 2008.

VTL are able to provide high-quality data about the traffic, as well as help to save confidentiality of separate persons, only opening the data in predetermined places in advance. One of the problems is in definition where VTL should be located in the whole network in order to collect correspondent traffic data not violating individual confidentiality or locating VTL so tight, that unnecessary data volume is transferred through telecommunication network. No researches reliably to appropriate VTL location for solving of these problems were not conducted until this day.

2. The flow theory

In the flow theory it is regular to simulate traffic flow in the form of continuum and present it with macroscopic flow variables $q(x,t)$ (auto/s), density (x,t) (auto/m) and speed $v(x,t)$ (м/s). Determination of the flow provides the following ratio between these three variables:

$$q(x,t) = \rho(x,t)v(x,t). \qquad (1)$$

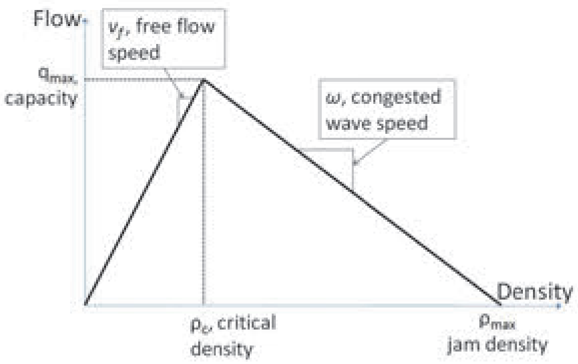


Fig. 1. Main diagram: empirically built line between the flow and density of vehicle

This property will be used in the conclusions of traffic frequency distribution.

At low meanings of density experimental data shows that speed of flow is reliably insensitive to density; all vehicle move close to the so-called free-stream speed v_f of the correspondent road section. Along with density increase the critical density ρ_c exists, at which the flow of vehicle achieves the road capacity q_{max}. Because of the fact that density of transport increases at ρ_c, speed monotone decreases to the null level at full density ρ_{max}. Full density can be considered to be full quantity of vehicle, which can be physically equal to the length unity and at such density vehicle cannot move without additional space between them. Experimental data indicates on the decreasing of linear dependence between the flow and density, because flow arises at ρ_c. Inclination of this line is named the speed of load wave, w. This leads to the common accepted hypothesis of triangular fundamental diagram (FD) for modeling of flow dynamics [9].

In such a way, triangular FD (fig. 1) is fully characterized by three parameters: v_f, free-stream speed (m/s); ρ_{max}, full density (auto/m); q_{max}, capacity (auto/m).

Let's notice that ρ_c represents the meaning of the border density between:

- the terms of free flow for which automobiles have equal speed and do not interact;
- saturated conditions at which density of vehicle forces them to slow down and the flow decreases.

When the queue dissipates, vehicle free from the queue with full throughput q_{max}, which corresponds to critical density $\rho_c = q_{max} / v_f$.

For this interesting road section the speed of arrival rate in the moment of time t, this means the flow of vehicle, including into the unit at t, is indicated as $q_a(t)$. Saving of the flow binds it with density of arrival $\rho_a(t) = q_a(t) / v_f$.

In arterial nets traffic is derived by forming and dissipation of queues on the intersections. Queue dynamics is characterized by the transfixions, which are formed on the boundary of traffic flows with two different densities.

3. Model production

Here two modes of discrete traffic: dense and load, which reflect different dynamics of arterial unit depending on the presence (respectively to absence) of the lack of queue, when the light switches from green to red. Fig.1 illustrates these two modes under the assumption of triangular FD. The speed of forming and solutability of the queue are indicated as v_a and w. Their expression is obtained from the terms of Rankine-Hugoniot jump [10, 11] and is assigned with the formulas:

$$v_a = \frac{\rho_a v_f}{\rho_{max} - \rho_a} \text{ и } w = \frac{\rho_c v_f}{\rho_{max} - \rho_c}.$$

3.1. Unsaturated mode

In this mode the queue is completely dispersed during the green time. This queue is named triangular queue (because its triangular form on the space-time diagram of trajectories). It is determined as space-time area, where vehicle stop on the line. Its length is named as full queue line, indicated as l_{max}, which also can be calculated of the traffic theory:

$$l_{max} = R\frac{wv_a}{w - v_a} = R\frac{v_f}{\rho_{max}}\frac{\rho_c\rho_a}{\rho_{max} - \rho_a}. \qquad (2)$$

Duration between the time, when the light becomes green and the time, when the queue is completely dispersed, - this is the time of purification, which is calculated as:

$$\tau = l_{max}\left(\frac{1}{w} + \frac{1}{v_f}\right). \qquad (3)$$

3.2. Overloaded mode

In this mode the queue part lower triangular queue, named remaining queue with l_r length correspondent to transport devices which should stop for several times before crossing exists.

All identifications represented here are illustrated for both modes on the fig. 2.

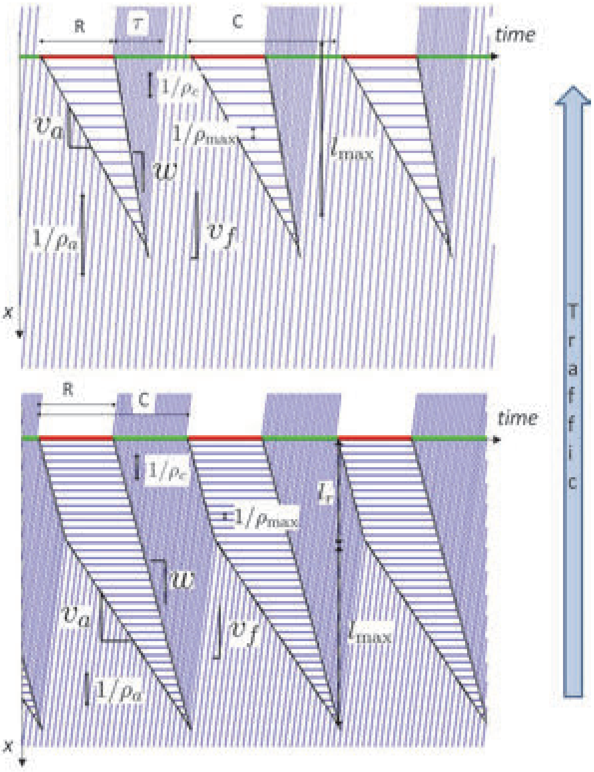


Fig. 2. Space-time diagram of vehicle with equal arrival in the mode of unsaturated traffic (from above) and in flow overload mode (from below)

3.3. Stationarity of two modes

Upon studies of the traffic modes statistic properties it can be often suitable to analyze their stationary behavior. The mode is determined as stationary, when cycle time (C), the red time (R), parameters of the main diagram (ρ_{max}; ρ_c; v_f) and density of input (ρ_a) remain steady during some period of time. Stationary means that queue evolution is frequent (fig. 2). As inclination of the trajectory shows on the picture, when vehicle are included into the link they are transferred with the speed of free flow v_f. The space between two vehicles is inversion of arrival density $1/\rho_a$. The time, during which vehicles stop in the queue. The length of this line represents delay, observed in correspondent queue. The space between vehicles, remained in the queue is inversion of maximal density $1/\rho_{max}$. When the queue dissipates, automobiles low down with the speed v_f and density ρ_c. Trajectory is represented by the line with inclination v_f, the space between two vehicles is equal to $1/\rho_c$.

3.4. Model traffic parameters

Model traffic parameters represent network characteristics [12]. They are specific for the line i and time interval t and represent dynamic condition of the traffic in different time intervals $t \in \{0...T\}$.

ρ_{max}^i	Maximal line density i.
q_{max}^i	Traffic capacity (maximal flow) on the line i.
ρ_c^i	Critical line density i.
w^i	$\rho_c^i v_f^i (\rho_{max}^i - \rho_c^i)$, shock wave reverse speed i.
v_f^i	Free flow line Speed i.
p_f^i	Free line flow temp (free flow reverse speed) i. Let's notice that $p_f^i = 1/v_f^i$
L^i	Line length i (not parameter model, but the road attribute which is frequently used).

3.5. Traffic signal parameters

Traffic signal parameters characterize the properties of traffic signals in the end of the line i.

C^i	Duration of green cycle on the line i.
R^i	Duration of red cycle on the line i.

3.6. Variable conditions of the flow

Traffic conditions variables describe the traffic conditions, which characterize dynamic of the traffic in the network. Link to the line or temporary interval can be ignored if conclusions are not connected with the line or time.

$\rho_a^{i,t}$	Density of arrival on the i during time interval t.
$v_a^{i,t}$	$\rho_a^i v_f^i (\rho_{max}^i - \rho_a^{i,t})$, the speed of the arrival shock wave on the line i during time interval t (the queue speed because of additional automobile arrival).
$v_a^{i,t}$	$R^i w^i v_a^{i,t} / (w^i - v_a^{i,t})$, The length of triangular queue of the line i during the time interval t.
$\tau^{i,t}$	$l_{max}^{i,t}(1/w^i + 1/v_f^i$, The pure time duration on the line i during time interval t, when the queue should be cleared in unsaturated mode (is determined only for saturated mode).
$l_r^{i,t}$	The length of remaining queue, when red color is turned on (determined only for overloaded mode).

This set of variables is enough for the model characteristics and temporary traffic condition evolution. In particular, for determination of traffic condition, assigned with the traffic parameters it is necessary to use only $l_r^{i,t}$ and one of the $\rho_a^{i,t}$; $v_a^{i,t}$, $v_a^{i,t}$ or $\tau^{i,t}$. Location of x at the link corresponds to the distance from the place to intercrossing down the stream. Another traffic variables including the speed v, the flow q and density ρ of transporting in any moment x and time t.

For tightness the following functions are used. In general, each function often has another form dependent on the fact if unsaturated or overload mode is considering. The low index s is used for determination of the mode of specific functions form, which can be unsaturated u or overload, c.

$d^{s,i}(t)$	The time of passing the line i for vehicle, included into a segment in the moment of time t (in permanent time area) for the mode s.
$\delta^{s,i}(t)$	Retention function for this location x along the line i in the mode s.
$g^{s,i}(y_{x_1,x_2}$	Density (in the sense of probability) deallocation time y_{x_1,x_2} between locations x_1 and x_2 along the line i for the mode s.

3.7. Temporary flow diagrams through the signal intersections.

Analytical templates of intercrossing delays are developed for unsaturated and overload modes. The first mode appears when the queues can be absolutely purified during the green cycle phase, while the queues cannot be purified during one cycle and remaining in the queue would have to wait additional cycles. In special situations (for example, intensive overload) the queues can flow up at the crossing lines and cause further delays.

Following the model of traffic flow theory through the signal intersections the function of flow time $d(t)$ is derived. This function represents the time, necessary for transporting, included into the segment in the moment of time t crossed the intersection. Further one line is considered (that is why index i is excluded of indications and it is intended that parameters of the channel are fixed during the analysis time period (that is why index of temporary interval t is excluded). Here t is related to the concrete time moment in permanent time area.

Minimal time of movement at the line is equal to the time on the channel transfer with the free flow speed, taking into account the presumption that all transporting move with the speed of free flow, if they are not stopped. Minimal time of movement is names as free movement time and is equal to $\frac{L}{v_f}$. If the light is red or the queue is present, when transporting approaches to the crossing of the down-flow, transporting binds to the end of the queue and in such a way it is delayed. Otherwise, if transporting achieve crossing when the light is green and with no queue, transporting will cross the road crossing without a delay (in such a way, the time of free-wheeling passing). What is more important, while analyzing triangular geometry in space-time diagram (fig. 2), it is not difficult to notice that if transporting enters the line during the time which would allow to achieve the crossing immediately after the red light (it is assumed that there were no interrupting), delay for this vehicle will be maximal for a concrete cycle.

After this the delays will locally decrease, until their full absence. Inclination b movement time functions might be analytically calculated (it is possible to see this on the fig. 2):

$$b = \frac{v_f(w - v_a)}{w(v_f + v_a)} = -1 + \frac{\rho_a}{\rho_c}. \tag{4}$$

Here w is a wave speed, v_f the speed of the free flow, v_a is a wave speed, when vehicle binds to the queue, ρ_{max} is a jam density and ρ_a is a density of arrival, which is considered to be invariable during the cycle. Three parameters v_f; w; ρ_{max} are specific for actual arterial locations, which also determine the basis of the line scheme. Using the formula (4), movement time function for unsaturated mode is calculated in the following way:

$$d^u(t) = \frac{L}{v_f} + \max\left\{0, R + b(t + \frac{L}{v_f})\right\}$$
$$\text{for} \quad -\frac{L}{v_f} \le t < C - \frac{L}{v_f}, \tag{5}$$

where $t = 0$ is determined as the time, when the light becomes red. The function is periodic, the period is equal to signal cycle time, that is why $d^u(t) = d^u(t + kC)$, $k \in Z$.

Let's notice that analysis and formula which is given above (5) work only in unsaturated mode, when minimal retention achieves 0 in each cycle. In overload mode remaining queue l_r should wait additional cycles, entitled to depuration. In this situation delay linear decrease from maximal meaning after the beginning of red light time (when automobile arrives to the road crossing). However retention never achieves zero. Instead of this it will have a sudden increase from zero retention to another maximal retention, which indicates on the fact that automobile will have to wait one more cycle. Inclination of curves can be analytically calculated, having looked on the geometry of forming and unloading of triangular (fig. 2). During executing of the stationary terms the function inclination of movement time is the same as in unsaturated mode (calculated in the formula (4)). The difference for overload mode is in the calculation of retention for the remaining queue. At first, maximal quantity of vehicle stops will be performed before exit.

$$n = \left(\frac{l_r}{l_{max}}\right), \tag{6}$$

$$tt_{min} = \frac{L}{v_f} + \left((n-1) + \frac{l_r - (n-1)l_{max}}{l_{max}}\right)R. \tag{7}$$

This leads to the expression for movement time function for overload mode:

$$d^c(t) = tt_{min} + \max\{0, R + b(t + tt_{min})\}$$
$$\text{для} \quad -tt_{min} \le t < C - tt_{min}, \qquad (8)$$

where $t = 0$ is again time, when the light becomes red (for some particular cycle). As well as in unsaturated case this function is periodical with a period equal to the cycle time.

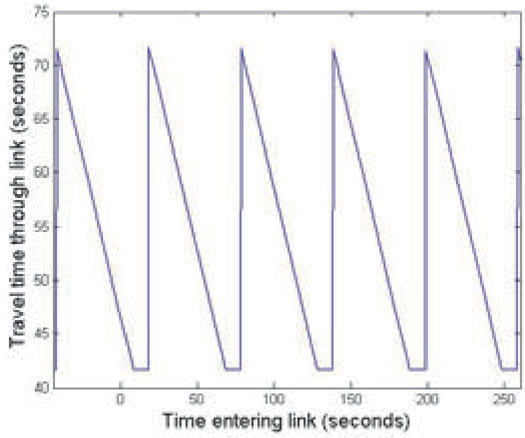
On the fig. 3 the function of movement time function is depicted in unsaturated and overload modes for the line parameters assigned set. Let's notice that both unsaturated and overload functions are piecewise-linear. These two functions are so similar that it is not difficult to calculate the function of single movement time in the way of setting $tt_{min} = \frac{L}{v_f}$ at $l_r = 0$ (unsaturated mode), then the formula (8) represents both unsaturated and overload modes.

3.8. Distribution of movement probability

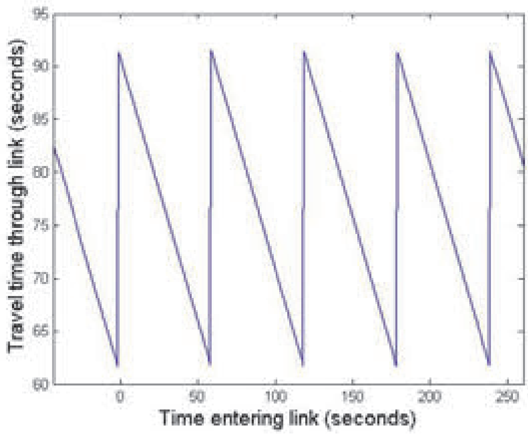
Above the theoretic movement time function for vehicle which are suitable at the signal network line. However, without measuring of the movement time from a big part of vehicle, passing on the line, it is impossible to restore this function directly. The speed of penetration of test vehicles will be not enough high to make this reconstruction until the time when almost all vehicles will be controlled, that is why it is necessary to develop another method for determination of the traffic conditions of more sparsed data. With this aim the concepts introduces above are used, but with the random selection of vehicle point of view arbitrarily across the network. The aim is to develop probability distribution for transmission time along the line, which is line parameters function.

The way time of vehicles, moving along arterial networks is specified with two factors. Firstly conditions of the traffic which are given by the network parameters determine the traffic condition tested with vehicle. Secondly, the time (relatively the beginning of light cycle) on which the transport arrived along the line. Arrival time determines how many retentions will occur because of the traffic signal presence and presence of another vehicles (movement conditions). When conditions of the movement are analogical the drivers are facing the different time on the way depending on arrival time. Using the assumption that density of arrival (and, consequently, the speed of input) is constant, the marks of arrival time evenly divide according to the duration of the light cycle. This allows to obtain assignment of passing time probability, which depend on traffic light characteristics and movement conditions.

It is possible to obtain the difference in time on arterial connections using accepted here modeling assignments. Arterial line is determined as the road length between two signal intersections. Sample electrode vehicles can send information about the trip time between arbitrary initial and finite locations along the line. Transmission time from the place x_1 to the place x_2 along the line (с x_1 is higher by the flow from x_2) is named as partial line transmission time from x_1 to x_2 and is designated y_{x_1,x_2}. Free flow transmission time between x_1 and x_2 is defined as trip time arising at moving with the speed of free flow p_f. The difference between moving time and free flow moving time is named as delay.



a – Unsaturated mode ($d^u(t)$)



b – Overload mode ($d^c(t)$)

Fig. 3. Theoretic function of channel transmission time for unsaturated (a) and overload modes (b). The channel length was 500 meters and signal parameters were 60 seconds cycle time and 30 seconds red time.
Free flow transmission time was 42 seconds and the length of remaining queue for overfilled corps was 100 meters

Assignment of the time probability $g_u(y)$ on the arterial line in unsaturated mode

$$g_u(y) = $$
$$= \begin{cases} 0 & \text{if } y \le 0; \\ \frac{1-\eta}{L}\varphi\left(\frac{y}{L}\right) + \frac{\eta}{R}\left(\Phi\left(\frac{y}{L}\right)\right) & \text{if } y \in [0, R]; \\ \frac{1-\eta}{L}\varphi\left(\frac{y}{L}\right) + \frac{\eta}{R}\left(\Phi\left(\frac{y}{L}\right) - \Phi\left(\frac{y-R}{L}\right)\right) & \text{if } y \ge R, \end{cases}$$

where $\Phi(x) = \int_{-\infty}^{\infty} \varphi(x)dx$ cumulative function of function assignment φ, which is assignment function for the free flow speed. This result means that for vehicles which stop in the queue the delay is uniform from 0 to the red cycle duration (dependent on the fact what time did the automobile arrive). Some percent of automobiles should not stop and these vehicles meet free movement time. Assumption that the drivers have some distribution of the free flow speed results is used in the combination with the law of full probability in order to obtain the full continuous distribution of the driving time.

Transmission probability distribution time $g_c(y)$ on the arterial time in overload mode

$$g_c(y) = $$
$$= \begin{cases} 0 & \text{if } y \le 0; \\ \frac{1}{\delta_{max} - \delta_{min}}\left(\Phi\left(\frac{y-\delta_{min}}{L}\right)\right) & \text{if } y \in [0, R]; \\ \frac{1}{\delta_{max} - \delta_{min}}\left(\Phi\left(\frac{y-\delta_{min}}{L}\right) - \Phi\left(\frac{y-\delta_{max}}{L}\right)\right) & \text{if } y \ge R, \end{cases}$$

where δ_{min} and δ_{max} is maximal delay including the length of the line queue. Let's notice, that $\delta_{max} - \delta_{min} = R$, determines overload mode. This means some minimal delay for vehicle exists, because the definition of overload mode is that each vehicle stops as minimum one time in the queue. The delay is evenly distributed on the background diapason and then full distribution of moving time is calculated according to the law of full probability again.

3.9. Time distribution in the way

Functions g_u and g_c quasi convex and function of logarithmic likely hood, determined for g_u and g_c, is absolutely not convex. It is determined as

$$ll(P) = \sum_{j=1}^{n} \ln(g_s(y_{x_{j,1}, x_{j,2}})), \quad (9)$$

3.10. Regression model of the traffic for estimating and forecasting

The model of arterial traffic conditions with the usage of GPS-sample electrode data is represented here as the only data source. Represented model uses the system on the basis of VTL as the only source of input data. This model is based on the regression methods, which are considered to be standard in the statistics community and two variants are represented: one with the discrete presentation of the traffic condition and one with the continuous presentation.

The usage of regression model for estimation service level indicator (LosS), which represents the total travel time and overloads condition for the network of automobile roads is described below. After the presentation of common regression models (p. 3.10.1) the common problem of perception on the graph (3.10.2) with subsequent formal definitions of LoS indicators (p. 3.10.3).

3.10.1. Assumptions

A few common key assumptions, which allow to use regression models for compromising exist. At first it is expected that infrastructure based on VTL gathers the data about the moving time between all neighboring VTL pairs in the road system. VTL pairs are basic building block for these models. It is expected that all the data and estimations of models have a type of transmission time for each pair of VTL. Besides, the models estimate average time of discrete time interval and do not estimate distribution of trip time probability. The second common suggestion is that a discrete number of overload conditions exists for each VTL pair and that this condition number is equal for all VTL pairs.

3.10.2. Graphic model of the road network

Let's consider arterial network with deployed N and VTL pairs. Each pair has unique identification number $i \in \{1, ..., N\}$. The set of all VTL pairs is designated as $V = \{1, ..., N\}$. Each VTL pair has a road section between them with a possibility of one or several road objects, such as crossing (with or without a traffic light), footpaths, signs stop/slowly and so on. These road characteristics can be statistic (for example, the presence of stop sighting) or dynamic (for example, phase of signal crossing). Travel time, conducted by a vehicle, passing through a VTL pair depends on the road characteristics as well as limitations of demand capacity, stipulated with the flow moving dynamics.

The up flow (respectively down) VTL for the pair i is VTL, at which the traffic introduces (respectively remains) the road section. For the pair i let upper and lower VTL be correspondently designated as i_u and i_d. The net of VTL sensors can be represented as oriented graph $G = (V, E)$, where V is a set of all pairs VTL, as it was earlier designated, and E a set of all ribs. Two VTL pairs i and j form a rib, directed from the pair i to the pair j, designated e_{ij}, if i_d and i_u correspond to one VTL. Then i (respectively j) is named increasing (correspondently decreasing) rib node e_{ij}.

Let's determine a set of the neighbors of the first order for VTL pair j as

$$N^1(j) = \{j\} \cup \{i \in Ve_{ij} \in E\} \cup \{k \in V : e_{jk} \in E\},$$

which is just a set of all VTL pairs up and down along the flow for pair j (which includes namely the pair j).

Aforementioned definition can be spread on the following neighbors of n order $n \geq 1$):

$$\begin{cases} N^0(j) = \{j\} \\ N^n(j) = N^{n-1}(j) \cup \end{cases}$$
$$\cup \left(\bigcup_{l \in N^{n-1}(j)} \{i \in V : e_{ij} \in E\} \cup \{k \in V : e_{jk} \in E\} \right). \quad (10)$$

3.10.3. Traffic indicators on the level of the service

It is assumed that for any VTL pair $i \in V$ the data about transmission time are available in the moment of time $0 \leq t_1 \leq t_2 \leq \ldots$. The pace can also be used as alternative presentation of the data about the trip time (the trip time, divided by the road length for the VTL pair). The data, obtained in the moment of time t_1 for the VTL pair i are denoted as $X_{t_{1,i}}$ (i.e. the trip time or pace of vehicle transmission of the VTL i pair, starting from the time t_1).

Because obtained data is based on the events they cannot be directly used for prepare of the statistic models, which require regular sampling rates (i.e. one quantity for a discrete time step). In order to solve this problem, the data on moving time aggregates into t seconds windows for obtaining of observation time-series in the moments of time $k = 0, t, 2t, \ldots$. Here t is an interval of aggregation. Further k is used for the definition of time interval $[(k-1)t, kt]$. The set of available observations for the period of time k for any VTL pair i is denoted as $A_{k,i}$, this means,

$$A_{k,i} = \{X_{t_{m,i}} \mid (k-1)t \leq t_m < kt\}.$$

Let's define a function of dimensioned aggregation for the VTL pair $i, h_i(\cdot) : A_{k,i} \mapsto [0, \infty)$, as a function, which is summing the set of observations $A_{k,i}$ in the aggregate representative amount, denoted as $Z_{k,i}$. In the remaining part of this section $Z_{k,i}$ – aggregated moving transmission time (in seconds). In such a way, aggregated transmission time for VTL i during k interval is equal to

$$Z_{k,i} = h_i(\{X_{t_{m,i}} \mid (k-1)t \leq t_m < kt\}).$$

The VTL pair mode is defined as category variable, indicating on the level of retention, arising at transmission through the VTL pair. For example, classification of the double mode can be unload or overload. In such a way, the VTL pair modes can be also interpreted as overload condition. Let's the mode of VTL i pair during some time interval k to be designated as $Q_{k,i}$. In order to transform the common observation quantity, acceptable to the VTL i pair during the time k in the condition of overload, the function of overload indicator is defined as $g_i(\cdot) : A_{k,i} \mapsto \{1, \ldots, M\}$, where M is a number of overload conditions. M is a metaparameter of the model, which is chosen on the basis of preliminary data analysis for a considered section. A few meanings of M might be chosen in order to see which one is better. With this definitions $Q_{k,i}$ is defined

$$Q_{k,i} = g_i(\{X_{t_{m,i}} \mid (k-1)t \leq t_m < kt\}).$$

From the statistic modeling point of view both cumulative speed and transmission time $Z_{k,i}$ and overload condition $Q_{k,i}$ for $i \in V$ and $k \in \{0, 1, \ldots\}$ might be considered as accident processes, generating by the phenomena of the flow movement in space-time in arterial net. Both $Q_{k,i}$ and $Z_{k,i}$ might be considered as LoS indicators.

Conclusions

This article represents the new approach to the estimation of arterial traffic, based only on the GPS-sample electrode and without information about the sensor of fixed location.

The regression model of traffic estimation for traffic conditions discrete classification (logical regression). The key problems for solution in regression models were processing of non-processed data in the format which is expected by the standard regression algorithms. The problem is solved by development of the user's aggregation functions – for initial representative quantity and quantity of the discrete classification, which were built with usage of knowledge in the field of vehicular traffic in combination with the analysis of imperial data. Summarizing with regression approaches, the most important lesson was that the quality of aggregation function was that the quality of aggregation functions was ultimately determining factor for the success of regression algorithm. This fact means that approaches to the regression can potentially be very successful at the traffic conditions estimation.

Obtained results in the work promotes the growth of smartphone industry with GPS support, as well as another sources for providing information about the vehicle traffic in the mode of real time to the drivers and transit agencies.

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МОДЕЛЬ АВТОМОБІЛЬНОГО АРТЕРІАЛЬНОГО ТРАФІКУ ЗА ДАНИМИ ПОТОКОВОГО GPS-ЗОНДУ

Нух Таха Насіф

У цій статті розроблена модель артеріального трафіку на основі розріджених даних GPS-зразка. Система моніторингу трафіку в основному обмежена магістралями і спирається на державні або приватні канали передачі даних зі спеціалізованої дослідницької інфраструктури, яка часто включає в себе петльові детектори, радари, відеокамери. Системи GPS існують вже кілька десятиліть, проте лише протягом останніх десятиліть пристрої, які можуть надавати високоточну інформацію для відстеження при відносно низьких витратах. Це призвело до використання дешевих GPS-пристроїв виявлення, розташованих в транспортному засобі для збору інформації про трафік. Основною перевагою електрода GPS-зразка є те, що умови потоку можуть бути змінені всюди, де датчики потрапляють. Артеріальна мережа являє собою додаткові завдання моделювання і оцінки, оскільки фізика потоку, яка регулює їх, складніше через світлофора (зазвичай з невідомими циклами), перетинів, стоп-знаків і паралельних черг. Пропонована статистична модель заснована на досягненнях в декількох областях, включаючи теорію потоку.

Ключові слова: *артеріальний трафік, GPS, моніторинг трафіку, маршрут, регресійна модель.*

МОДЕЛЬ АВТОМОБИЛЬНОГО АРТЕРИАЛЬНОГО ТРАФИКА ПО ДАННЫМ ПОТОКОВОГО GPS-ЗОНДА

Нух Таха Насиф

В настоящей статье разработана модель артериального трафика на основе разреженных данных GPS-зонда. Системы мониторинга трафика в основном ограничиваются автомагистралями и опираются на государственные или частные каналы передачи данных из специализированной зондирующей инфраструктуры, которая часто включает в себя петлевые детекторы, радары, видеокамеры. Система GPS существует уже несколько десятилетий, однако только в течение последнего десятилетия появились устройства, которые способны предоставлять высокоточную информацию отслеживания при относительно низких затратах. Эта разработка привела к использованию дешевых GPS-следящих устройств, размещенных в транспортных средствах для сбора информации о трафике. Основным преимуществом данных GPS-зонда является то, что условия движения могут быть измерены везде, куда попадают датчики. Артериальная сеть представляет собой дополнительные задачи моделирования и оценки, поскольку физика потока, которая их регулирует, более сложна из-за светофоров (часто с неизвестными циклами), пересечений, знаков остановки и параллельных очередей. Предложенная статистическая модель основывается на достижениях в нескольких областях, включая теорию движения.

Ключевые слова: *артериальный трафик, GPS, мониторинг трафика, маршрут, регрессионная модель.*