Research Paper Presentation

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Topic

A Probability-Based Analytical Model Based on Deep Learning for Traffic Information Estimation

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Abstract

- We will determine the PDF model based on deep learning to analyze the relationships between the number of call arrivals and vehicle speed.
- We will discuss about vehicle speed estimation method to estimate vehicle speed in accordance with the number of call arrivals.
- We will study traffic flow estimation method to estimate traffic flow in accordance with the number of normal location updates.
- We will also study traffic density estimation method to estimate the traffic density in accordance with the estimated vehicle speed and the estimated traffic flow.
- Finally we will check accuracy of the model using simulation results.

Error function

- Also called the Gauss error function and denoted by erf.
- A Complex function of a complex variable defined as:

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} \, dt \tag{1}$$

- This integral is a special (non-elementary) sigmoid function

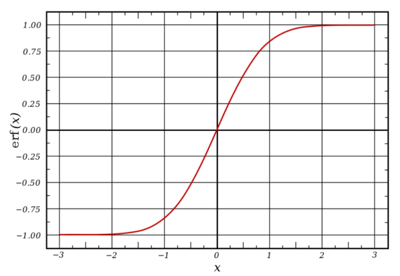

Figure: Plot of the Error function

Error function contd

- Occurs oftenly in probability, statistics, and partial differential equations.
- Estimate results that hold with high probability or low probability.
- Given a random variable $X \sim Norm[\mu, \sigma]$ and constant $L < \mu$:

$$\Pr(X \leq L) = \frac{1}{2} + \frac{1}{2} erf\left(\frac{L-\mu}{\sqrt{2}\sigma}\right) \tag{2}$$

PTV VISSIM

- A microscopic multi-modal traffic flow simulation software package.
- Complete software package for traffic analyses, forecasts and GIS-based data management on city, regional or national levels.

TRAFFIC INFORMATION ESTIMATION

Introduction

- Due to advance in science and technology, the intelligent transportation system (ITS) is becoming more powerful.
- Real-time traffic information plays a significant role in ITS.
- The methods to gather real-time traffic information are divided into three categories:
  1. Vehicle detectors (VDs)
  2. Global position system (GPS)
  3. Cellular floating vehicle data (CFVD).
- Compared with other two methods, CFVD is characterized by low cost and large data volume and can also avoid privacy issues.

TRAFFIC INFORMATION ESTIMATION

Cellular floating vehicle data (CFVD)

- CFVD is a method to determine the traffic speed on the road network based on the collection of localization data from mobile phones in vehicles that are being driven.
- It collects the traffic information by tracking the movements of mobile stations (MSs) using cellular network signals.
- Some of the mainly used cellular network signals:
  1. Normal Location Update (NLU)
  2. Handover(HO)
  3. Call Arrival (CA)

Vehicle Speed Estimation

Probability-Based Analysis

- Adopts the number of CAs to estimate vehicle speed.
- Relationships between the number of CAs and traffic information were modelled in accordance with probability functions.
- The distribution of call inter-arrival time was assumed to be an exponential distribution.However, the practical distribution may be not an exponential distribution.
- Therefore, it uses deep learning techniques and adopts CDFs of exponential distribution, normal distribution and log-normal distribution to learn the CDF of call inter-arrival time.
- The call inter-arrival time is adopted as the input of neural network, and the CDF is adopted as the output of neural network.

Probability-Based Analysis contd

- As shown in Figure, a mobile station(MS) in the car moving along the road performs the first call set-up (at time t_0) and then enters $Cell_i$ coverage (at time t_1). It subsequently performs the second call set-up (at time t_2) before leaving $Cell_i$ coverage (at time t_3).

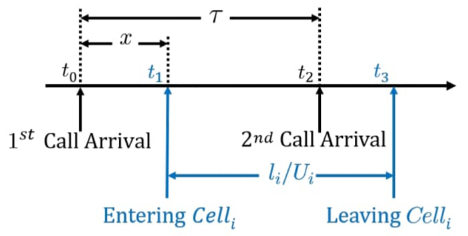

Figure: The timing diagram for vehicle movement and CA on the road

Vehicle Speed Estimation

Probability-Based Analysis contd

- Using deep learning techniques and adopting the CDFs of exponential distribution, normal distribution and log-normal distribution, the relationship between the number of CAs and vehicle speed is expressed as Equation (3).
- Some of the notations used in the equation are :
  - The practical vehicle speed, traffic flow and traffic density of $Cell_i$ are denoted as U_i, Q_i and K_i.
  - The number of CAs of $Cell_i$ is denoted r_i.
  - The parameters μ_1, μ_2, μ_3, σ_2 and σ_3 are the weights of the proposed activation functions in the neural network.

Probability-Based Analysis contd

$$
\begin{aligned}
r_i &= Q_i \times \Pr\left(t_1 < t_2 < t_3\right) \\
&= \mu_1 \left(1 - e^{-\frac{1}{\mu_1}\left(\frac{1}{u_i}\right)}\right) + \frac{l}{2u_i} - \frac{1}{2}\left(\frac{l}{u_i} - \mu_2\right) erf\left(\frac{\frac{l}{u_i} - \mu_2}{\sigma_2\sqrt{2}}\right) + \\
&\quad \left(-\frac{1}{2\mu_2}\right) erf\left(\frac{-\mu_2}{\sigma_2\sqrt{2}}\right) - \frac{\sigma_2\sqrt{2}e^{-\left(\frac{l^2-l_2}{\frac{\sigma_2}{2}}\right)^2}}{2\sqrt{\pi}} \frac{\sigma_2\sqrt{2}e^{-\left(\frac{\mu_2}{\frac{\sigma_2}{2}}\right)^2}}{2\sqrt{\pi}} \\
&\quad + \frac{l}{2u_i} - \frac{1}{2}e^{\mu_3+\frac{\sigma_2^2}{2}}\left(erf\left(\frac{-\ln\frac{l}{u_i} + \mu_3 + \sigma_3^2}{\sigma_3\sqrt{2}}\right) - 1\right) \\
&\quad - \left(\frac{l}{2u_i}\right) erf\left(\frac{\ln\frac{l}{u_i} - \mu_3}{\sigma_3\sqrt{2}}\right) \qquad (3)
\end{aligned}
$$

Vehicle Speed Estimation

Estimation Based on Deep Learning

- The probability-based analytical model indicates that the relationship between the number of CAs and vehicle speed is significant.
- Trains another neural network to estimate vehicle speed in accordance with the number of CAs.
- The input is the number of CAs and vehicle speed is adopted as the output of neural network.

Traffic Flow Estimation

- Assumes that the actual traffic flow on the road segment covered by $Cell_i$ is Q_i and one MS is in each vehicle.
- The NLU event is generated when an MS moves from a location area (LA) to another LA.
- The number of NLUs (q_i) is equal to traffic flow (Q_i) while a vehicle is passing through a LA.

$$q_i = Q_i \tag{4}$$

Traffic Density Estimation

- Denoted by k_i and estimated according to the estimated vehicle speed (u_i) and the estimated traffic flow (q_i).
- The traffic density (k_i) is given by the equation (5),

$$k_i = \frac{q_i}{u_i} \tag{5}$$

SIMULATION ANALYSIS

- The practical traffic information were adopted as simulation data in this study.
- The practical information contained road conditions and vehicle movement behaviors.
- The vehicle movements were generated by VISSIM.
- Assumptions according to the statistical results:
  - l_i=1.0 km
  - μ_i =1 call/h
- Generates random numbers of call inter-arrival time with normal distribution for each MS.
- The accuracies of vehicle speed estimation and traffic density estimation are described as $1 - \frac{|U_i - u_i|}{U_i}$ and $1 - \frac{|K_i - k_i|}{K_i}$.

SIMULATION ANALYSIS contd

Cell	U_i	K_i	u_i	k_i	$1-\frac{\lvert U_i-u_i\rvert}{U_i}$	$1-\frac{\lvert K_i-k_i\rvert}{K_i}$
1	81.27	64	80.06	64.65	96.13%	95.98%
2	80.68	64.37	80.83	63.98	96.71%	96.95%
3	80.29	64.68	79.86	64.79	96.66%	96.73%
4	80.06	64.84	80.51	64.21	95.46%	95.59%
5	79.92	64.98	79.76	64.84	96.73%	96.72%
6	79.8	65.08	78.88	65.59	96.74%	96.93%
7	79.69	65.19	79.99	64.66	96.42%	96.51%
8	79.58	65.28	80.27	64.43	96.50%	96.66%
9	79.57	65.31	80.32	64.29	95.35%	95.62%
10	79.48	65.38	79.73	65.07	96.85%	96.80%
average					96.36%	96.45%

Table: SIMULATION RESULT

From the above Table, the accuracies of estimated vehicle speed and estimated traffic density were 96.36% and 96.45%.

THANK YOU