# ECTI e-magazine

# In this Issue...

Message from Editor	Page 2
Review Article ("Acquiring Fundamental Traffic Variables with Mobile Sensors")	Page 3
Paper list of ECTI Transaction (CIT, EEC)	Page 11
Reports from Conferences/Seminars/Workshops	Page 12
Announcements/Upcoming events/Call-for-Papers	Page 16
ECTI Who's Who	Page 20

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# Message from Editor

Dear Valued ECTI Members,

In this issue of ECTI E-Magazine, the last one in 2017, we are pleased to publish a review article titled "Acquiring Fundamental Traffic Variables with Mobile Sensors" by Assoc.Prof. Dr. Sooksan Panichpapiboon (King Mongkut's Institute of Technology Ladkrabang). It describes recent research trends in intelligent transportation system with the focus on availability and access of traffic variables today and the future.

Next year, a number of interesting conferences will be held, particularly, the ECTI-CON 2018 (Chiangrai), ECTI-CARD 2018 (Phitsanoulok), ITC-CSCC 2018 (Bangkok), ISCIT 2018 (Bangkok), among others. I urge the members as well as the public in this region and the world to register for these events. The conference gathering is important for academic people, technicians, researchers and industrial sector to learn new ideas, progress as well as socialize at excellent locations. Some of these conferences have reduced rates and even offer limited travel fees for ECTI members.

In addition to the activities/Workshops of each Technical Area as well as the ECTI Association, list of articles in the ECTI Journals, upcoming sponsored conferences and seminars, we welcome the articles related to the activities, collaboration projects at your research group, laboratories or research centers. Should you have any comments or suggestions to improve the ECTI E-Magazine so that it serves our members better, please do not hesitate to contact us via E-mail (ecti.emagazine@gmail.com) or ECTI Association Facebook.

From next year, the new committee members (2-year terms) will start working. I hope that members will continue to volunteer your time in various activites, and importantly, supports the ECTI Association in the years to come.



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2

# Acquiring Fundamental Traffic Variables with Mobile Sensors

#### Sooksan Panichpapiboon

### ABSTRACT

Fundamental traffic variables such as speed, density, and flow are important for modeling the traffic dynamics. A traffic model lets us understand how the traffic behaves and helps us regulate it better. In addition, real-time traffic information has become a crucial element of intelligent transportation. With real-time traffic information, human motorists as well as autonomous vehicles will be able to select the most efficient routes to their destinations. Acquiring accurate traffic data is the heart of any traffic information system. Traditionally, raw traffic data are obtained from fixed sensors that are installed in an infrastructure-based traffic information system. These data are then processed and transformed into meaningful traffic variables such as speed, density, and flow. However, it is foreseeable that vehicles will be used as mobile traffic sensors in the near future. Consequently, what used to be obtainable easily with fixed sensors in an infrastructurebased system may no longer be obtainable when mobile sensors are used. New methods for acquiring accurate traffic variables with mobile sensors are required. In this article, we discuss how the fundamental traffic variables are typically obtained in the traditional fixed sensing system and explore how they can be obtained in the new mobile sensing paradigm.

#### **Keywords**

Traffic sensing; Vehicular sensing; Mobile sensors; Intelligent transportation systems

### I. INTRODUCTION

Real-time traffic information is an essential element of intelligent transportation in a smart city. With the real-time traffic information, human motorists as well as autonomous vehicles will be able to select the most efficient routes to their destinations. Moreover, it also allows dynamic rerouting to be done wisely in the case that a traffic incident occurs. The traffic information is not only resourceful to the road users, but it is also valuable for the authorities. Historical traffic data have been used extensively by the authorities in transportation planning, design, and operation.

Currently, many cities have their own traffic information systems, which are capable of reporting up-to-date traffic condition to the motorists. However, most of the current traffic information systems are an infrastructure-based system, where the traffic data are collected from fixed



Figure 1: A typical infrastructure-based traffic information system.

sensors such as inductive loop detectors and surveillance cameras. A typical infrastructure-based traffic information system is shown in Fig. 1. It mainly consists of three parts: (i) the sensors, (ii) the data collection center, and (iii) the information outlets. The sensors are installed on the road to collect the traffic data. The most commonly used sensors are inductive loop detectors and surveillance cameras. The traffic data collected by these sensors are then passed to the data collection center for processing. Finally, the data collection center processes the data and disseminates the traffic information back to the motorists through various kinds of information outlets, including traffic display boards, websites, social media, etc.

Relying on fixed sensors, however, has many shortcomings. First, the sensors need to be installed on the road network. This usually takes a great deal of time and efforts. For example, installing inductive loop detectors would involve digging up the road surface. Second, maintenance of these sensors in the system is troublesome. Third, it is expensive to install fixed sensors to cover a large area (e.g., city-wide or state-wide coverage). Finally, data in the areas where there are no sensors installed cannot be collected.

With an emerging new technology such as connected vehicles (also known as vehicular ad hoc networks or VANETs) [1], [2], a paradigm shift in traffic sensing is on its verge. With this technology, vehicles will be able to act as mobile sensors and collect the traffic data as they travel. They may also disseminate and share the traffic information with others. Hence, traffic sensing can be shifted from the fixed sensing approach to a mobile sensing approach. A mobile sensing system has many advantages over the traditional infrastructure-based sensing system. First, it is a lot more convenient to install sensors on a vehicle than on a road. Sensors could be installed on a vehicle by the vehicle manufacturer, or they could be installed later as add-ons by the vehicle owner. Second, maintenance of these sensors becomes much simpler. Sensors can be inspected regularly when a vehicle is taken for its scheduled checkup. Finally, and most importantly, vehicles can travel anywhere in the road network; therefore, the traffic data can be collected from everywhere.

In addition to the connected vehicles technology, advances in the mobile devices technology also make mobile sensing even more realizable. Mobile devices such as smartphones and tablets are now equipped with a variety of sensors such as global positioning system (GPS) receiver, accelerometer, gyroscope, camera, and microphone. These sensors can be exploited to collect traffic data. Moreover, smartphones are now adopted by a large number of users. Consequently, a person with a smartphone can turn any vehicle, whether new or old, into a mobile traffic sensor. This makes smartphones a great choice for mobile traffic sensing devices.

Nonetheless, using vehicles as traffic sensors brings many new challenges. Since the sensors now become mobile and distributed, the methods and algorithms that have been used for sensing, extracting, and processing the traffic data in the traditional infrastructure-based sensing system may no longer be applicable. There is a stark difference between the types of measurements that a fixed sensor and a mobile sensor make. Fixed sensors are typically designed to collect spot measurements, which are measurements at a specific observation point over time. For example, an inductive loop detector collects a count of vehicles at an observed location on a roadway over time. In contrast, the mobile sensors move along with the traffic stream and do not make measurements at a specific spot over time. Moreover, the traffic variables that are easily collectable by the fixed sensors might no longer be obtainable easily with mobile sensors. For example, vehicle counting can be done easily with a loop detector. However, it is not trivial to count the number of vehicles passing an intersection with a mobile sensor, especially in the practical situation where only some of the vehicles on the road are equipped with the sensors. Hence, the new ways of sensing and extracting the traffic information will be needed.

The rest of this article is organized as follows. In Section II we discuss how the fundamental traffic variables such as speed, density, and flow are obtained in a traditional infrastructure-based sensing system. In Section III, we explore how these important traffic variables can be obtained in a mobile sensing system. Finally, we conclude this article in Section IV.

# II. ACQUIRING TRAFFIC VARIABLES WITH FIXED SENSORS

The three fundamental traffic variables that are used to describe the macroscopic traffic dynamics are speed, density, and flow. These three variables are related through the well-known fundamental relation [3], which can be written as

$$f = \rho v \tag{1}$$

where *f* is the traffic flow rate,  $\rho$  is the traffic density, and v is the space mean speed. In this section, we describe how each of these fundamental traffic variables are obtained in the traditional infrastructure-based sensing system.

#### A. Speed

The average speed is a macroscopic variable that measures how fast the vehicles in the traffic stream move. It is typically measured in a unit of m/s or km/h. In an infrastructurebased sensing system, an inductive loop detector is usually used to sense and collect the speed of a passing vehicle. An inductive loop detector is a sensor which is implanted on a road surface [4]. When an object (e.g., a vehicle) passes over or lays on top of the loop detector, it changes the inductance of the loop. The change in the inductance indicates the presence of an object, and the knowledge of the presence/absence of an object can be used for vehicle counting. Furthermore, by using two inductive loop detectors, the speed of a vehicle can be determined. In order to determine the vehicle speed, two detectors will be placed and separated by a known distance, denoted by d. The time at which a vehicle passes the first detector, denoted by  $t_{I_i}$  and the time at which it passes the second detector, denoted by  $t_{2i}$  will be recorded. The vehicle speed can simply be obtained from  $d/(t_2 - t_1)$ . The speed of each passing vehicle can then be aggregated at the data collection center, and the average speed of the vehicles during a specified period can be calculated.

Many modern infrastructure-based sensing systems use cameras as sensors for collecting the traffic data. Typically, cameras will be installed highly above ground in order to get an overlooking view of the traffic scene. A video stream from each camera will be relayed to the data collection center for processing. The speed of each vehicle in the camera scene can be obtained through feature tracking. By tracking the positions of the vehicles over consecutive video frames, it is possible to determine the distance that each vehicle moves per unit of time [5]–[8]. This allows the system to determine the speed of each vehicle passing the camera as well as the average speed of the vehicles in the traffic stream.

#### B. Density

Density is a traffic variable that measures the spatial occupation of vehicles per unit road length. It basically indicates how packed the vehicles are on the road. Density is measured in a unit of vehicles per meter (veh/m). The most direct way to measure the traffic density is by counting the number of vehicles that are simultaneously present on the observed road space. This may be done through aerial photography. For example, a satellite image can provide an aerial view of a road section, and thus the number of vehicles on the section can be counted from the image. However, aerial photography might not be practical, especially for a long-term solution which regularly makes measurements. As a result, traffic density is usually derived indirectly from other traffic variables. In an infrastructurebased sensing system that uses inductive loop detectors, the traffic density can be derived indirectly from other traffic variables collectable by them. In [9]-[11], traffic density is derived from the speed and flow data collected by inductive loop detectors. In [12], traffic density is estimated from the ratio of the number of vehicles that moves between a pair of loop detectors and the distance between them. In addition, the traffic density can also be indirectly derived from the percent occupancy, which is the percentage of time that a point on a road is occupied by vehicles [3]. Intuitively, if a point on a road is occupied for a larger fraction of time, it suggests that the traffic is denser. For example, 100% occupancy implies that a point on the road is always occupied, and this suggests that the traffic is extremely dense.

In a traffic information system that uses video cameras as sensors, the traffic density can be estimated from the number of vehicles in the traffic scene. Basically, the effective road area in the scene will be defined, and the number of vehicles that are simultaneously present in the area will be counted. There are a number of algorithms for vehicle detection and counting [13]–[16]. The data collection center can use these algorithms to process the video stream and acquire the traffic density in the observed area.

#### C. Flow

Flow rate is a traffic variable that measures the number of vehicles passing an observation point per unit of time. It has a unit of vehicles per second (veh/s). It is straightforward to determine a flow rate in an infrastructure-based system because a vehicle count can be obtained easily from a fixed sensor. With an inductive loop detector, a flow rate can be determined effortlessly from the number of vehicles that passes over the detector in a specified time period. With a traffic camera, a flow rate can be determined from the number of vehicles that passes the camera scene. Basically, an image/video processing algorithm can be used to count the number of vehicles crossing a reference point in the traffic scene per unit of time. This idea is quite similar to that of the inductive loop detector, and thus it is usually referred to as the virtual loop detector. Image and video processing techniques for vehicle identification, classification, and counting can be found in [17]–[19].

# III. ACQUIRING TRAFFIC VARIABLES WITH MOBILE SENSORS

As the emerging technologies empower the vehicles to be connected, mobile traffic sensing becomes increasingly more appealing. In this section, we discuss how each of the fundamental traffic variables could be obtained in a mobile sensing manner.

#### A. Envisioned mobile sensing system

In mobile traffic sensing, some vehicles will act as sensors and collect the traffic data. The traffic data will then be passed to an online data collection center. These data will then be processed and distributed back to the road users through a variety of outlets such as websites, social media, and mobile applications. In order to understand how each type of the fundamental traffic variables can be collected with mobile sensing, it is important to layout some basic assumptions about the sensing system. Here are the assumptions in an envisioned mobile traffic sensing scenario.

• It is assumed that some of the vehicles will be equipped with sensors and communication devices. These vehicles will be referred to as sensing vehicles, which are capable of collecting, transmitting, and receiving data. Potentially, there are two types of technologies that can facilitate this. The first candidate is the connected vehicles technology. A typical connected vehicle will be equipped with sensors such as GPS receiver, camera, etc. In addition, a connected vehicle will be equipped with an on-board unit (OBU), which allows it to communicate with other vehicles through the vehicleto-vehicle (V2V) communication and allows it to communicate with an infrastructure through the vehicle-to-infrastructure communication. (V2I) Moreover, many OBUs also have a cellular interface; therefore, they will also be able to transmit and receive data via a cellular network. The other potential technology is the mobile devices technology. Mobile devices such as smartphones are now equipped with a variety of sensors, and they have become increasingly more powerful. A smartphone can conveniently be installed on a vehicle and used as a traffic sensing device. Ultimately, regardless of the underlying communication technology, each sensing vehicle will be able to relay the traffic data to the data collection center.



Figure 2: An example of a mobile traffic sensing system.

• Periodically, each sensing vehicle transmits the collected data to the data collection center. The data collection center then processes and disseminates the traffic information to the public through the information outlets

• The overall general system architecture is shown in Fig. 2.

#### B. Speed

Speed is probably the easiest traffic variable collectable by a mobile sensor. The most commonly used solution in obtaining a vehicle speed is by using a GPS receiver. With a GPS receiver, the position of a sensing vehicle can be tracked and its speed can easily be acquired. Periodically, each sensing vehicle sends its geolocation to the data collection center. The data collection center uses these data to estimate the speed of the sensing vehicle. With data from multiple sensing vehicles, the average speed on a particular road can be determined. Examples of mobile applications that use positions of their users for speed sensing are Google Maps and Waze [20]. Moreover, data do not have to come from private vehicles only. Many traffic information systems use public transport vehicles such as taxis and busses as sensing vehicles [21]-[23]. The accuracy of the estimated speed depends on the sampling rate of the GPS data. Generally, the more frequently the vehicle position is sampled, the more accurate the estimated speed is. However, there is a tradeoff between accuracy and energy consumption. A GPS receiver is a power-hungry sensor [24]. Using it continuously can quickly drain out the battery of the mobile device. As a result, a mobile sensing approach should also keep energy efficiency in mind.

There are several ways to reduce the energy consumption incurred by the GPS receiver. One way is to keep the sampling rate of the GPS receiver as low as possible. Of course, reducing the sampling rate affects the accuracy of the location and speed estimation [25]. Therefore, an appropriate sampling rate should be chosen carefully. In [26], the authors propose an approach to activate the GPS receiver when necessary. Basically, a GPS receiver is switched on only if it is detected that the user is in a "driving" mode. In this approach, different modes of user activities such as driving, walking, and running are classified using an accelerometer on a smartphone. By shutting off the GPS receiver when a user is not in the driving mode, the phone battery life can be prolonged.

Another way to be energy efficient is by using other sensors that consume less power than the GPS receiver. In order to reduce power consumption, a new approach in determining the average speed of a sensing vehicle is proposed in [27]. Instead of relying on the power-hungry GPS receiver, the average speed is estimated from the data sensed by an accelerometer, which consumes approximately six times less power than the GPS receiver [24]. In this approach, a smartphone is placed on each sensing vehicle. The accelerometer on the smartphone is then used to detect the state of the vehicle, whether it is moving or stationary. Periodically, each sensing vehicle sends a sequence of these states to the data collection center. The average speed of a sensing vehicle can be estimated from the sequence of its states. Basically, the length of an interval that a vehicle can move continuously is highly correlated with its average speed. Intuitively, if a vehicle can move continuously for a long period of time, its average speed tends to be high. On the contrary, if a vehicle has to stop frequently during its trip, then its average speed tends to be low. In [27], two methods for determining the average speed of a vehicle from its sequence of states are introduced. It is shown that they can achieve a satisfactory level of accuracy.

#### C. Density

In comparison to the infrastructure-based sensing system, it is more challenging to measure traffic density with mobile sensors. Unlike the infrastructure-based traffic sensing system, obtaining the number of vehicles that are simultaneously present on a road with distributed mobile sensors is not easy. One of the main reasons is that each mobile sensor does not have an overlooking view of the roadway (i.e., unlike having a fixed camera). Nonetheless, there are a number of counting-based density estimation approaches proposed in the literatures [28]-[32]. These approaches are mainly designed for VANETs, and they share the following common trait. Basically, if all vehicles are equipped and can communicate with one another, then a sensing vehicle will be able to check the number of its onehop neighbors. This allows a sensing vehicle to obtain the number of vehicles within its transmission range and the local density in its vicinity. The local density can further be used to estimate the actual density on the road. In addition to the number of neighboring vehicles, density can also be estimated from the number of vehicles that form a

connected cluster [29]. Unfortunately, these approaches only work under the assumption that all the vehicles on the road are equipped with the communication devices, which may be difficult to achieve in practice. Besides, if every vehicle on the road is equipped, each one of them can periodically send its location to the data collection center. In this way, the data collection center knows exactly how many vehicles are simultaneously present on a specific road, and the actual density on the road can be determined. However, it cannot be safely assumed that all the vehicles will be equipped and that all of them will be willing to share their location data. A practical density estimation approach should work in a situation where only some of the vehicles are willing to sense and share their traffic data.

There are also density estimation approaches that do not rely on the assumption that all vehicles must be equipped with the necessary sensing and communication devices. These density estimation approaches have to indirectly derived density from other quantities. In [33], a local density is determined from the fraction of time that a sensing vehicle stops during its trip. Basically, if the vehicle has to stop frequently, it is implied that the traffic is dense. In [34], the authors propose a density estimation approach for a situation where there is a mix of connected vehicles and ordinary vehicles. However, the density has to be estimated indirectly from the speed of the sensing vehicles. Basically, the speed is used to imply how dense the vehicles are. In addition, it is also required that the average speed of the connected vehicles and the average speed of the ordinary vehicles are approximately the same.

Fortunately, in addition to counting, there is also another possible way to straightly measure the traffic density. In fact, the traffic density can be obtained from its direct counterpart, the mean *space headway*. A space headway is defined as the distance between the same points on two successive vehicles. For example, a space headway can be measured from a rear bumper of the leading vehicle to the rear bumper of the following vehicle. Intuitively, if the average space between each pair of consecutive vehicles on the road is small, then it suggests that the traffic is dense. In fact, the physical relation between the traffic density and the mean space headway can be described as [3]

$$\rho = 1/E[X] \tag{2}$$

where  $\rho$  is the traffic density, *X* is a random variable denoting the space headway between each pair of consecutive vehicles, and *E*[*X*] is the mean of the space headway. In other words, the traffic density can be automatically obtained from the reciprocal of the mean space headway. With the direct physical relation between the traffic density and the space headway described in (2), the traffic density can be determined by letting the sensing

vehicles measure their space headways and report these measurements to the data collection center. With the space headway samples from multiple sensing vehicles, the data collection center will be able to estimate the mean space headway and the traffic density. Thus, the key is to obtain an accurate measurement of the space headway samples. There are many types of sensors that a sensing vehicle can use for estimating its space headway. In [35], an approach to estimate a space headway with a smartphone is introduced.

Assuming that each sensing vehicle can estimate a space headway, it can periodically report this information along with the geolocation and the time instant at which the sample is taken to the data collection center. With these space headway samples from multiple sensing vehicles, the data collection center can compute the sample mean of the space headway on a road at a specific point in time, and it can use the computed sample mean to estimate the traffic density with (2). More details on estimating the traffic density with mobile sensors can be found in [35].

#### D. Flow

Ideally, if all of the vehicles on the road are equipped with GPS receivers and communication devices, then the flow rate can be determined easily. In this case, each vehicle can report its location to the data collection center regularly. Based on these GPS data, the data collection center can acquire the flow rate at a particular location by counting the number of vehicles that passes the location in a specified time period. However, assuming that all vehicles can and will cooperate in reporting their geolocations to the data collection center is not practical.

One possible approach to determine the flow rate with mobile sensors in a scenario where only some of the vehicles are sensing vehicles is the following. Basically, each sensing vehicle can collect their geolocation and the space headway. As pointed out in the earlier sections, these two types of data can be collected using a smartphone. Periodically, each sensing vehicle can report these data to the data collection center. Note that these data will allow the data collection center to estimate the speed and the density on a road. The flow rate can further be estimated from the speed and the density using the fundamental relation in (1). However, model calibration still requires further investigation. In [36], the authors estimate the flow rate from the theoretical speed-flow models. Basically, they use the speed data obtained from probe vehicles and plug them into four different speed-flow models, namely Greenshield, Underwood, Northwestern, and Van Aerde, in order to find out which model yields the best flow estimation. The estimated flow rates are compared with the ground truth values obtained from the loop detector data collected on I-880 highway in San Francisco, California,

USA. It is shown that, among the four models, Van Aerde model yields the best results. However, the accuracy of this method is heavily affected by the validity of the applied speed-flow model. In addition, the estimation method may not work well in all traffic regimes.

#### IV. CONCLUDING REMARKS

Emerging technologies such as connected vehicles and smart mobile devices will transform the way the traffic data are collected and processed. These technologies empower the vehicles to become mobile sensors. Connected vehicles are anticipated to hit the road in the next few years. At least, the new vehicles will likely have such a technology onboard. As a result, many new vehicles will be able to help contribute the traffic data as they travel. Nonetheless, it will still take some time for the number of the connected vehicles to reach a critical mass as traffic sensors. Thus, in the beginning phase, connected vehicles will still be a small fraction of the total vehicle population. In order to increase the number of active mobile sensors and improve the penetration rate, an approach to turn an ordinary vehicle into a traffic sensor should also be considered.

Smart mobile devices such as smartphones, tablets, and smartwatches are a great option for traffic sensing devices. A smart mobile device can be placed on an ordinary vehicle and can turn the vehicle into a mobile traffic sensor. A smart device usually comes with a variety of built-in sensors. These sensors can be exploited to sense the traffic data. The key is to select an appropriate sensor for collecting the data required to obtain the traffic variables of interest. Smart mobile devices, especially smartphones, are adopted by a large number of users. Thus, if used as traffic sensing devices, they can help boost the number of mobile traffic sensors tremendously.

Finally, since the types of raw data that the mobile sensors can collect may be different from those obtained by the fixed sensors, new approaches are required to process and transform these data into meaningful traffic variables. In this article, we have discussed a variety of ways to acquire the three fundamental traffic variables, namely speed, density, and flow, from the data collected by the mobile sensors. For speed estimation, it is most convenient to use the GPS data collected from the mobile sensors. However, it should be kept in mind that a GPS receiver consumes a lot of power. As a result, it can drain out the device battery quickly. An alternative solution for speed estimation is to use an accelerometer which consumes much less power [27]. For traffic density, it is possible to determine the density from the reciprocal of the mean space headway [35]. Flow is, perhaps, the most difficult variable to acquire from the mobile sensors. However, assuming that speed and density are obtained, the flow rate could be estimated from the fundamental relation.

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#### BIOGRAPHY



Dr. Sooksan Panichpapiboon received the B.S., M.S., and Ph.D. degrees from Carnegie Mellon University, Pittsburgh, PA, USA, in 2000, 2002, and 2006, respectively, all in electrical and computer engineering. In April 2008, he was a Visiting Researcher with the Department of Information Engineering,

University of Parma, Parma, Italy. He is currently an Associate Professor with the Faculty of Information Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand. His current research interests include intelligent transportation systems, vehicular ad hoc networks, mobile sensors, and performance modeling.

Dr. Panichpapiboon was a recipient of the ASEM DUO-Thailand Fellowship in 2007. He received the Doctoral Dissertation Award from the National Research Council of Thailand in 2011. He received the Siew Karnchanachari Award for Electrical Engineering in 2015. He is a Senior Member of the IEEE.

# More About the Authors...



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### Education

• Ph.D. in Electrical and Computer Engineering Carnegie Mellon University, Pittsburgh PA, USA

#### Research Interests

- Intelligent Transportation Systems
- Vehicular Ad Hoc Networks
- Wireless Sensor Networks

### List of Selected Publications

- 1. S. Panichpapiboon and P. Leakkaw, "Traffic Density Estimation: A Mobile Sensing Approach," IEEE Communications Magazine, Dec. 2017, to appear.
- 2. S. Panichpapiboon and P. Leakkaw, "Traffic Sensing Through Accelerometers," IEEE Transactions on Vehicular Technology, vol. 65, no. 5, pp. 3559-3567, May 2016.
- 3. S. Panichpapiboon, "Time-Headway Distributions on an Expressway: Case of Bangkok," ASCE Journal of Transportation Engineering, vol. 141, no. 1, pp. 05014007, Jan. 2015.
- 4. S. Panichpapiboon and L. Cheng, "Irresponsible Forwarding Under Real Inter-vehicle Spacing Distributions," IEEE Transactions on Vehicular Technology, vol. 62, no. 5, pp. 2264-2272, June 2013.
- L. Cheng and S. Panichpapiboon, "Effects of Intervehicle Spacing Distributions on Connectivity of VANET: A Case Study from Measured Highway Traffic," IEEE Communications Magazine, vol. 50, no. 10, pp. 90-97, Oct. 2012.
- S. Panichpapiboon and W. Pattara-atikom, "A Review of Information Dissemination Protocols for Vehicular Ad Hoc Networks," IEEE Communications Surveys and Tutorials, vol. 14, no. 3, pp. 784-798, Third Quarter, 2012.
- 7. S. Panichpapiboon and W. Pattara-atikom, "Exploiting Wireless Communication in Vehicle Density Estimation," IEEE Transactions on Vehicular Technology, vol. 60, no. 6, pp. 2742-2751, July 2011.
- 8. S. Panichpapiboon, G. Ferrari, and O. K. Tonguz, "Connectivity of Ad Hoc Wireless Networks: An Alternative to Graph-Theoretic Approaches," Wireless Networks, vol. 16, no. 3, pp. 793-811, Apr. 2010.

# Paper List of ECTI Transaction

### ECTI-EEC Transaction: -

Website: http://www.ecti-eec.org/index.php/ecti-eec

Two issues are available annually. The next issue will be available soon.

ECTI-CIT Transaction: -Website: https://www.tci-thaijo.org/index.php/ecticit

Two issues are available annually. The next issue will be available soon.

# Report from Conferences/Workshops/Seminars/Events

ECTI-ICROS Joint Session on Advances of Control System Design @ ICCAS 2017

Date: Oct. 19, 2017 Venue: 17th International Conference on Control, Automation and Systems Phuket Graceland Resort & Spa, Phuket, Thailand Main Organizer: Prof. Dr. David Banjerdpongchai



### 6th Joint Seminar on Control Systems

Date: Nov. 24, 2017 Venue: Faculty of Engineering, KMUTNB Main Organizer: Asst. Prof. Dr. Chirdpong Deelertpaiboon



### ISAP 2017

Date: Oct. 30 – Nov. 2, 2017 Venue: Phuket Graceland Resort & Spa, Phuket, Thailand Submitted Papers: 452 (63 papers from Thailand) Accepted Papers: 411 Website: http://www.isap2017.org/index.php



#### STRI's Lecture Series

Date: Nov. 6, 2017 Venue: STRI, KMUTNB Speaker: Prof. Prabhakar Pathak, USF, USA



### IEEE ComSoc Distinguished Lecture Tour

Date: Dec. 25, 2017 Venue: Telecommunication Engineering Department, KMITL Topic: Ambient Backscatter Assisted Wireless Powered Communications Speaker: Prof. Dusit Niyato, NTU, Singapore



# Announcements/Upcoming events/Call-for-Papers

การ ประชุมวิชาการ งานวิจัย และพัฒนาเชิงประยุกต์ ครั้งที่ 10



# ECTI-CARD 2018 ารประยุกต์ใช้งานเทคโนโลยีเพื่อตอบสนองนโยบายประเทศไทย 4.0

26 - 29 มิถนายน พ.ศ. 2561

ณ จังหวัดพิษณุโลก

# 1<sup>st</sup> Call For Papers

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Secretary เศรษฐา ตั้งค้าวานิช (มน.) งานประชุมวิชาการ ECTI-CARD 2018 ครั้งที่ 10 "การประยุกต์ใช้เทคโนโลยีเพื่อตอบสนองนโยบาย ประเทศไทย 4.0" จัดโดย คณะวิศวกรรมศาสตร์ มหาวิทยาลัยนเรศวร และสมาคมวิชาการไฟฟ้า อิเล็กทรอนิกส์ โทรคมนาคมและสารสนเทศประเทศไทย ระหว่างวันที่ 26 - 29 มิถุนายน พ.ศ. 2561 จังหวัดพิษณุโลก มีจุดมุ่งหมายหลักของการจัดงานเพื่อรวบรวบผลงานวิจัย งานนวัตกรรม ณ สิ่งประดิษฐ์ และการพัฒนาเชิงประยุกต์ รวมถึงเพื่อเปิดโอกาสให้นักวิจัย ผู้พัฒนา ผู้ใช้งาน และ หน่วยงานต่างๆ ได้มีโอกาสแลกเปลี่ยนเรียนรู้ทางวิชาการร่วมกัน อีกทั้งสามารถนำผลงานที่ตีพิมพ์ไป พัฒนาต่อยอดในระดับท้องถิ่น ระดับสากล และพัฒนาสู่ผลิตภัณฑ์ในเชิงพาณิชย์ได้ ซึ่งบทความที่ส่ง มานั้นจะได้รับการพิจารณาคุณภาพและความสมบูรณ์ของงานโดยผู้ทรงคุณวุฒิ บทความที่ได้รับการ คัดเลือกและได้นำเสนอในที่ประชุม ECTI-CARD 2018 จะได้รับการตีพิมพ์ในรายงานสืบเนื่อง ECTI-CARD (ECTI-CARD Proceedings) ซึ่งสามารถสืบค้นได้จากฐานข้อมูลของสมาคม ECTI

### หัวข้อบทความที่เกี่ยวข้อง

- กลุ่มที่ 1: การเกษตรอัจฉริยะ อตสาหกรรมการเกษตร กลุ่มที่ 7: การขนส่ง การควบคมจราจร การจัดการ กลุ่มที่ 2: เทคโนโลยีชีวภาพ การแพทย์ วิทยาศาสตร์
- กายภาพ วิทยาศาสตร์การกีฬา
- กลุ่มที่ 3: การประหยัดพลังงาน การจัดการพลังงาน บ้านอัตโนมัติ
- กลุ่มที่ 4: การเรียนการสอนทางไกล การศึกษาบันติง กลุ่มที่ 10: มาตรวิทยา การวัดและควบคุม คอมพิวเตอร์เอนิเมชัน

กลุ่มที่ 5: การกู้ภัย ระบบเตือนภัย และพยากรณ์

### การส่งบทความ (2 รูปแบบ)

 รูปแบบ บทความวิจัย เป็นบทความเต็มรูปแบบภาษาไทย หรือ ภาษาอังกฤษไม่เกิน 2 หรือ 4 หน้ากระดาษ A4 ในรูปแบบมาตรฐาน 2. คอลัมน์ของ IEEE โดยต้องกล่าวถึงที่มาและผลที่ได้รับ รายละเอียดและ/ หรือการนำไปใช้งาน ซึ่งเกี่ยวข้องกับหัวข้อใดหัวข้อหนึ่งหรือมากกว่า จาก กลุ่มต่างๆที่ได้กำหนดไว้

 รูปแบบ สิ่งประดิษฐ์และนวัตกรรม เป็นบทความเต็มรูปแบบ ภาษาไทย หรือภาษาอังกฤษ ไม่เกิน 2 หน้ากระดาษ A4 ใน รูปแบบมาตรฐาน 2 คอลัมน์ของ IEEE โดยผู้เขียนบทความ อาจนำผลงานหรือสิ่งประดิษฐ์ มาร่วมจัดแสดงในงานประชุมได้

### ติดต่อประสานงาน

คณะวิศวกรรมศาสตร์ มหาวิทยาลัยนเรศวร ต.ท่าโพธิ์ อ.เมือง จ.พิษณุโลก 65000 โทรศัพท์: 055-964371 โทรสาร: 055-964005

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- กลุ่มที่ 6: การสื้อสาร การสนับสนุนผู้ใช้ตามบ้าน เครือข่ายสังคม เครือข่ายไร้สาย
- อตสาหกรรม
- กลุ่มที่ 8: ธุรกิจการธนาคาร การท่องเที่ยว และการโรงแรม กลุ่มที่ 9: ระบบความปลอดภัย การควบคนการเข้าถึงการ ยืนยัน ตัวตน ระบบตรวจจับ
- กลุ่มที่ 11: วิศวกรรมและเทคโมโลยีอุตสาหกรรม
- กลุ่มที่ 12: STEM เทคโนโลยีการศึกษา
- กลุ่มที่ 13: หัวข้ออื่นๆ ที่เกี่ยวข้อง

### กำหนดการ

ส่งบทความฉบับสมบรณ์ วันที่ 5 กมภาพันธ์ 2561 ประกาศผลการพิจารณาบทความ วันที่ 1 เมษายน 2561 ส่งบทความต้นฉบับเพื่อตีพิมพ์ วันที่ 1 พฤษภาคม 2561 วันจัดประชุมวิชาการ วันที่ 26 - 29 มิถุนายน 2561



#### Preliminary call-for-papers TC-CSC The 33rd International Technical Conference on Circuits/Systems, Computers and Communications July 4 - 7 20 8 Bangkok , Thailand With the gre at success of the International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC) as the world leading conference devoted to the advancement of high technologies in Circuits/ Systems, Computers and Communications, we would like to invite all the scholars and experts around the world to attend the 33rd ITC-CSCC 2018 to be hosted in Bangkok, the City of Angels, Thailand. Topics The conference is open to researchers from all regions of the world. Participation from Asia Pacific region is particularly encouraged. Proposals for special sessions are welcome. Papers with original work in all aspects of Circuits/Systems, Computers and Communications are invited. Topics include, but not limited to, the followings Committee Members President Kosin Chamnongthai General Chair Lunchakorn Wuttisittikulkii Drganizing Chair Piya Kovintavewat meral Secretary Datchakorn Tancharoen Visite Deserver Cheir State Charles Allower Cherron Semiconductor Devices & Technology VISI Design Submission of Papers Submission of Papers Prospective authors are invited to submit original paper(s) of either MS Word or PDF format written in English. Abstract is limited to two pages of text and figures. Abstract can be submitted on the official website. If you have any trouble in preparing papers and online submission, please contact the Organizing Chair Piya Kovintavewat General Secretary Datchakorn Tancharoen -Technical Program Chair VLSI Design Sensors & Related Circuits conference secretariat Pisit Vanichchanunt Charnchai Pluempitiwiriyawej Warakorn Srichavengsup Local Arrangement Chair **Proceedings and Publications** Computers All registered participants are provided with conference proceedings. Moreover, authors Artificial Intelligence conference proceedings. Moreover, authors of the accepted papers are encouraged to submit full-length manuscripts to IEIE JSTS (Korea), IEICE Transactions (Japan), or ECTI Transaction (Thailand). Papers passed through the standard review procedures of the IEIE JSTS and IEICE Transactions will be published in regular issues while ECTI Trans-actions and Engineering Journal will be published in special issues. The authors (or their institute) are requested to pay the publication charge for the IEIE JSTS or IEICE Transactions when their paper is accepted. Ammical intelligence Image/Speech Processing Internet Technology & Applications Computer Systems & Applications Multimedia Service & Technology Pongsatorn Sedtheetorn Chairat Phongphanphanee Special/Tutorial Session Chair Pornchai Supnithi Poompat Saengudomlert Computer Vision Face Detection & Recognition Chaodit Aswakul Security Wiroonsak Santipach Watermarking Sinchai Kamolphiwong Krek Piromsopa Data Mining and Big Data Analytics Chanon Warisarn hair Wannaree Wongtrairat Cloud computing - Engineering Education **Publication Chair** Publicity Chair Watid Phakphisut Registration Chair Vitawat Sittakul Transactions when their paper is accepted. Communications Activity Chair Kampol Woradit Suvit Poomrittigul

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The 15th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology or ECTI-CON 2018 is the fifteenth annual international conference organized by Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI) Association, Thailand. The conference aims to provide an international platform to present technological advances, launch new ideas and showcase research work in the field of electrical engineering, electronics, computer, telecommunications and information technology. Accepted papers will be published in the Proceedings of ECTI-CON 2018 and will be submitted for inclusion in the IEEE Xplore. Acceptance will be based on quality, relevance and originality.

#### **Technical Tracks**

Special Sessions

- Devices, Circuits and Systems
   Computers
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- 6. Electrical Power Systems
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A proposal for a special session can be submitted to the special session chair before the deadlines. The session topic can be varied upon one's interest but still relate to the role of Electrical / Electronic Engineering, Computer, Telecommunication, Computer and IT.

#### Best Paper Awards

Paper with the highest score of a track that holds more than 10 papers will be nominated as a "Best Paper Award" paper.

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Deadline for Special Session Proposal Deadline for Submission Notification of Acceptance Deadline for Final Manuscript Submission Deadline for Early Registration Conference Dates 15 December 2017 15 January 2018 27 April 2018 25 May 2018 25 May 2018 18 - 21 July 2018

 Prospective authors are invited to submit original full papers WITHOUT authors' names and affiliations, in English, of 2-4 pages in standard IEEE two-column format only, reporting their original work and results, applications, and/or implementation in one or more of the listed areas.

2) Papers must be submitted online only through the submission system of the conference website.
3) At least one author of each accepted paper MUST register and present the paper at the conference in order that the paper is to be included in the program. The program will also be submitted for inclusion in the IEEE Xplore.

#### **Further Publication**

Paper Submissions

Potential papers are encouraged for their extension and submit to ECTI Journals (ECTI-EEC or ECTI-CIT) for further publication.

#### Supports and Scholarship

Post graduate student whose paper is outstanding and has applied for the scholarship will be nominated for a partially supported scholarship. The grant is neither transferrable nor claimed in other forms.

More information is available at http://www.ecti-con.org/con-2018/







# **ISCIT 2018**

# The 18th ISCIT 2018, Bangkok Thailand "Communication and IT for Smart City" Sep 26 -28, 2018

The 18th International Symposium on Communications and Information Technologies (ISCIT 2018) will be held in Bangkok, city of angles, ISCIT 2018, under the technical sponsorship of IEEE, will provide a forum for researchers, engineers and industry experts to exchange and discuss new ideas, recent development, and breakthroughs in IoT, communications and information technologies. ISCIT2018 will also offer an exciting social program. Accepted and presented papers will be published in the conference proceedings and submitted to IEEE Xplore as well as other Abstracting and Indexing databases.

### Important Date

Date	Details
May 27, 2018	Paper submission deadline
April 29, 2018	Proposals for workshops, Tutorials and Special Sessions
July 1, 2018	Paper acceptance notification
July 29, 2018	Author registration Camera-ready paper submission

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