TRAFFIC ANOMALY DETECTION FOR SURFACE STREET NETWORKS WITH THE MESH-WISED TRAFFIC INDICES ON MACROSCOPIC FUNDAMENTAL DIAGRAM

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ABSTRACT

This paper describes the incident detection method for the surface street network based on the mesh-wised traffic indices which is called Traffic Scope. The Traffic Scope has been proposed for the visual comprehension of regional traffic situations in terms of the fluidity and the singularity of traffic conditions based on Macroscopic Fundamental Diagram. Through the dozens of case studies with real floating car data in Tokyo, we have so far found the singularity index has high sensitivity to the incident occurrence which will affect the traffic condition on surface street network. As an incident becomes serious, the area size affected by the incident will be larger. This implies us we may estimate the seriousness of the incident by counting the meshes which have higher singularities. In this paper, let us first introduce the concept of the Traffic Scope followed by the investigation on incident detection in Tokyo area.

INTRODUCTION

Recent telematics service provides traffic information via an on-board car navigation unit or a portable navigation device which facilitates interactive use. In Japan, car manufacturers provide their own telematics services based on FCD combining with VICS, the sensor based traffic information system in Japan. The information provision via a navigation unit produces much 'personalized' knowledge which reflects the user's preference, alternative routes to the destination, vehicle queues near the current position, etc. However, it is only provided to the limited number of drivers who correctly tell their destinations to the navigation units. Although there is no statistics, it is believed that the number of such drivers is small so that the influence of the telematics would be limited.

Another limitation of the present telematics is just providing the information to en-trip drivers who have already chosen car use in place of public transportation. Although the recent eco-conscious movement raises people’s motivation to have the information provision which encourages them more to use public transport, the present telematics for en-trip drivers is not enough to let the people reconsider the car use in daily life. This means the present telematics does not reduce the traffic demand. It is said the possible mitigation of traffic congestion will not be high without any traffic demand management.

As for pre-trip drivers, they might require the perspective view of the traffic congestion over the city for their decision making. Most of the people have some knowledge on the recurrent traffic conditions through their experiences. However, for non-recurrent traffic conditions, their knowledge would not help their decision making any more. The non-recurrent conditions should be informed with a comprehensive picture highlighting anomaly congestions which may caused by incidents.

So far, we have proposed the mesh-wised traffic information, named Traffic Scope, which will be broadcasted to many people for their quick comprehension on the rough sketch of regional traffic conditions (Horiguchi *et al.*, 2010). The Traffic Scope consists of two indexes in terms of the fluidity and the singularity of traffic conditions based on Macroscopic Fundamental Diagram (MFD). Through the dozens of case studies with real floating car data (FCD) in Tokyo, we have so far found the singularity index has high sensitivity to the incident occurrence which will affect the traffic condition on surface street network. As an incident becomes serious, the area size affected by the incident will be larger. This implies us we may estimate the seriousness of the incident by counting the meshes which have higher singularities.

In this paper, let us first introduce the concept of the Traffic Scope followed by the investigation on incident detection in Tokyo area.

CONCEPT OF TRAFFIC SCOPE

(Daganzo, 2007) extends the well-known idea of fundamental diagram (FD) for traffic flow on a simple section to network flows, that is so-called macroscopic fundamental diagram (MFD) for homogenously congested areas relating 'production' (Q: the product of average flow and network length) and 'accumulation' (K: the product of density and network length). The MFD is basically to be estimated with the travel speeds of all vehicles running in the area. Even though we do not know the movement of entire vehicles, however, (Geroliminis & Daganzo, 2007) suggested that the MFD can be estimated from FCD with the field experiment data in Yokohama (Sarvi *et. al.*, 2003).

The concept of the Traffic Scope is quite different from the conventional link-based traffic information which will be mainly used to estimate the travel time or to find better alternative route to the destination with the aim to increase the users' benefit. The Traffic Scope, on the other hand, based on mesh-wised information which does not represent the traffic condition of any certain road but quantifies the average fluidity and the singularity of the traffic conditions for all roads in the mesh by using MFD. It is aiming to suppress the traffic demand by letting the people recognize the whole picture of the real traffic condition and consider ceasing driving when the traffic condition is heavy.

As for the mesh-wised traffic information, we have introduced the following two indices, the fluidity index and the singularity index (Horiguchi *et al.*, 2010).

Fluidity Index

The fluidity index quantifies how far the present traffic condition is from the origin of MFD along the approximated curve. Figure 1 shows the plots of the aggregated traffic conditions for weekdays and holidays and their approximated curve in a certain mesh whose size is 1x1 km^2. As the dot for a mesh gets far from the origin and close to the top of the approximate curve, it means the traffic condition of the mesh closes to saturation and the fluidity may lose smoothness.

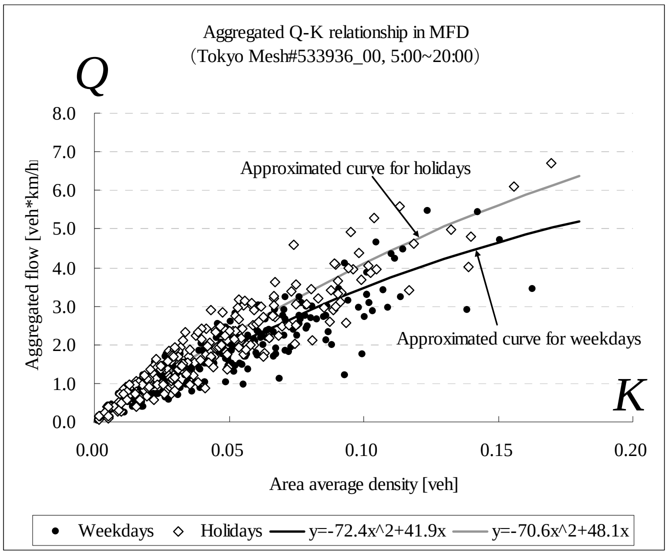

Figure 1: Plots of the aggregated traffic conditions and their approximated curve on MFD.

Singularity Index

The singularity index is aiming to know how different from the ordinary. It is an extension of the quantity of information for traffic congestion proposed by (Horiguchi & Wada, 2004) which calculates the entropy of the aggregated traffic condition of certain time period according to the probability density function of traffic conditions on MFD. Even though a mesh has low fluidity index at certain time, it may have low singularity index when the extent of the congestion is ordinary level for that time. If the mesh has high fluidity index to the contrary, it may have high singularity when the traffic is unusually light because of the extraordinary demand reduction in some disasters or incidents.

Tokyo Traffic Scope

We have so far implemented the real time monitoring system with the Traffic Scope for Tokyo city centre (Traffic Scope, 2011) by using real time FCD from 3000 taxis. The system aggregates the trip time and trip distance of the in-service taxis for every 15 minutes for each 1x1 km^2 mesh, and calculate the fluidity and the singularity indexes based on the statistics over the last 3 months.

Figure 2 shows an example of the Tokyo Traffic Scope. The colour scale shows the fluidity. The red colour means low fluidity with heavy congestion and the blue colour does high fluidity. The thickness of the colour shows the singularity index. It is highlighted by the thick colours when the singularity of a mesh is higher than 95% tile value over 3 months from September to November 2011. Through this picture, people may see the distribution of the congestion over the city and will roughly understand the traffic condition around their habitat or business places. At the same time, they will see how the congestion in the Tokyo city centre is extraordinary.

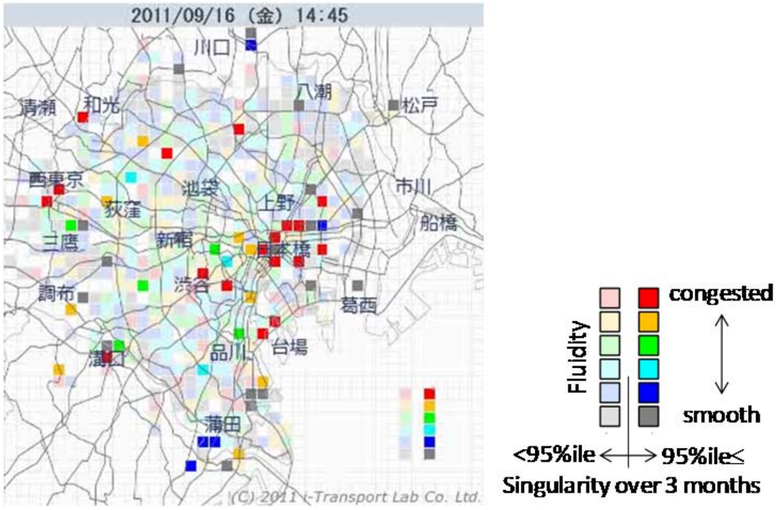

Figure 2: Mesh-wised 'fluidity (left)' and 'singularity (right)' indexes at the same time.

INCIDENT DETECTION WITH TRAFFIC SCOPE

Difficulty in the Incident Detection on Surface Streets using FCD

As the conventional incident detection mainly investigated expressways where traffic sensors are densely installed, there seems few works investigated surface street networks because of the poor installation of sensors. FCD can be a better source because of the wider coverage for surface streets in urban area. (Horiguchi & Wada, 2004) developed the methodology to detect the irregular time-space trajectory of FCD disturbed by the unexpected congestion which may be caused by traffic incident. Through the field operation test in Yokohama, it was found that the methodology quickly detected such unexpected congestion. However, the methodology will be suffered to lose its quick response by the low penetration of floating cars, since it only works when at least one floating car runs through the subject section.

Even though we can expect relatively higher penetration of floating cars, there still remain some problems to utilize FCD for incident detection. It will be the case when a traveling floating car encounters a heavy congestion and if it has enough intelligent to remind the alternative route avoiding that congestion, the traffic condition on the interesting route will not be updated. In real data, the floating cars tend to be equipped and to become intelligent to avoid congestion, we often see such dilemma. The lack of the necessary FCD may lose the quick response for incident detection, and it may sometimes mislead drivers not to avoid the heavy congestion.

Advantage to Use Mesh-wised Aggregated Traffic Condition

Even if we face such dilemma, it is expected that the re-route of an intelligent floating car will increase its travel time and distance comparing to the situation without the incident. Therefore, if we take the traffic condition aggregated within some adequate area, it will possible to detect the change caused by the incident. Since the singularity index of the Traffic Scope is the quantity of the status change from average condition, it is expected to find crucial traffic condition by monitoring the total singularity index in the subject area.

Preliminary Study on Incident Detection with Tokyo Traffic Scope

In order to validate the idea described above, we have investigated the changes on the total fluidity index and the total singularity index in Tokyo city center. The figure 3 shows those two indexes for every 15 minutes over 3 months from September to November 2011. With the focus on the singularity, the biggest peak is found on 20th September, and the second on is on 14 November.

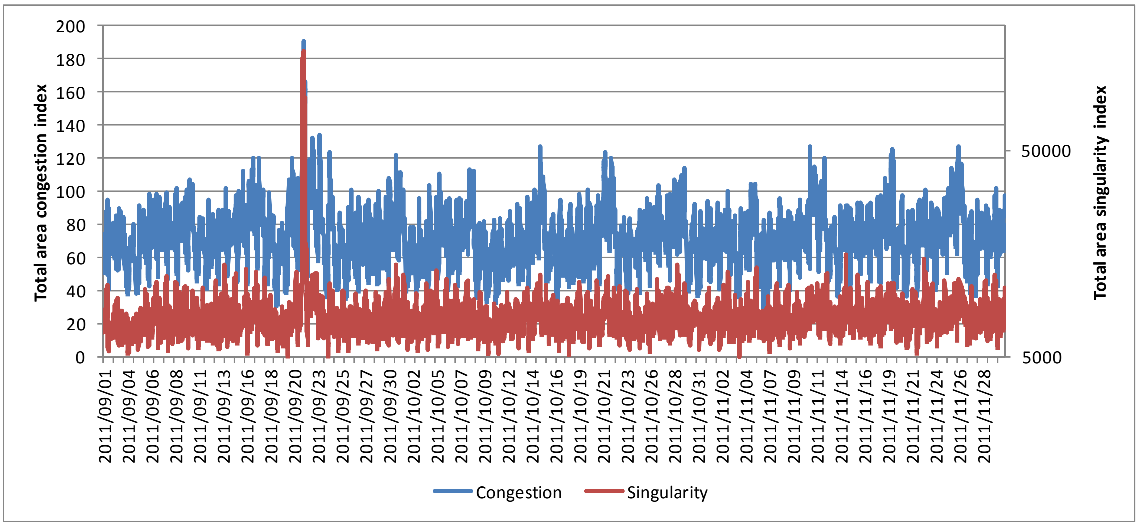

Figure 3: Changes on the total fluidity and the total singularity in Tokyo city centre (over 3 months).

The figure 4 enlarges the same graph of the figure 3 at around the biggest peak. On this day, the singularity rapidly increases at around 4 pm, and retains high level until midnight. The figure 5 shows the pictures of the Tokyo Traffic Scope for every 15 minutes at around 4 pm. From these pictures, we may recognize the extreme congestion first arose just before 4 pm in the western area (Shinjuku), and was growing to outbound. The other congestions which arose bit later were similarly growing from Tokyo city centre to outbound.

The reason for this day was clear that the typhoon #14 passed by Tokyo in the afternoon and it stops most of the trains at the evening peak of commuting time. As many companies stopped their business and let the employee go home in early time despite of train stopping, the exceeding traffic to the outbound from Tokyo caused extreme congestion.

The figure 6 enlarges the second peak same as above and we may see the singularity peak from 9 to 10 pm. The figure 7 shows the pictures of Tokyo Traffic Scope during that period. In this case, the extraordinary congestion in the north-western part (enclosed by the hand written polygon) was highlighted with the thick colours of high singularities.

During this time, the railway to the north-west had some trouble and the trains on that rail were stopped for a while. In such situation, many people would get off trains and take taxies to go home. Furthermore, many empty taxies hearing the news of the railway trouble would crowd around the railway stations. Such concentration of taxies might cause the extreme congestion on the arterial roads near-by the stations.

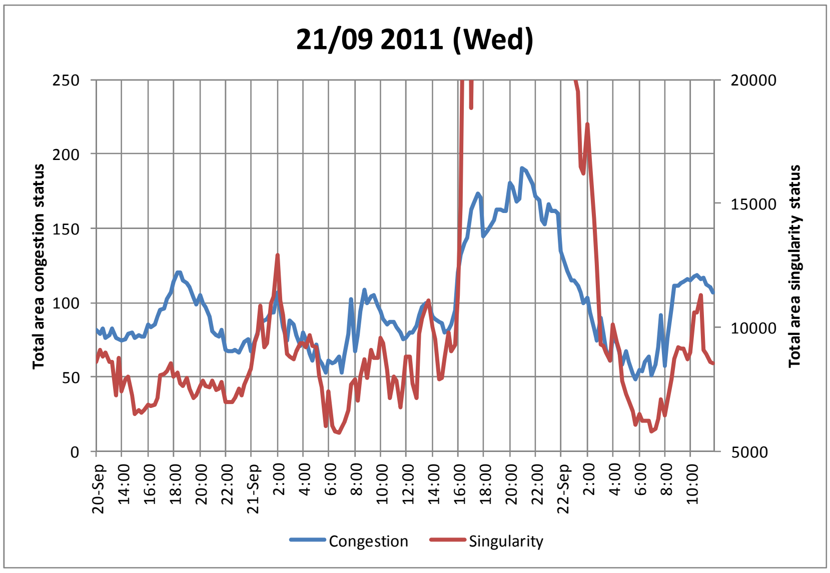

Figure 4: Changes on the total fluidity and the total singularity in Tokyo city centre (the biggest peak).

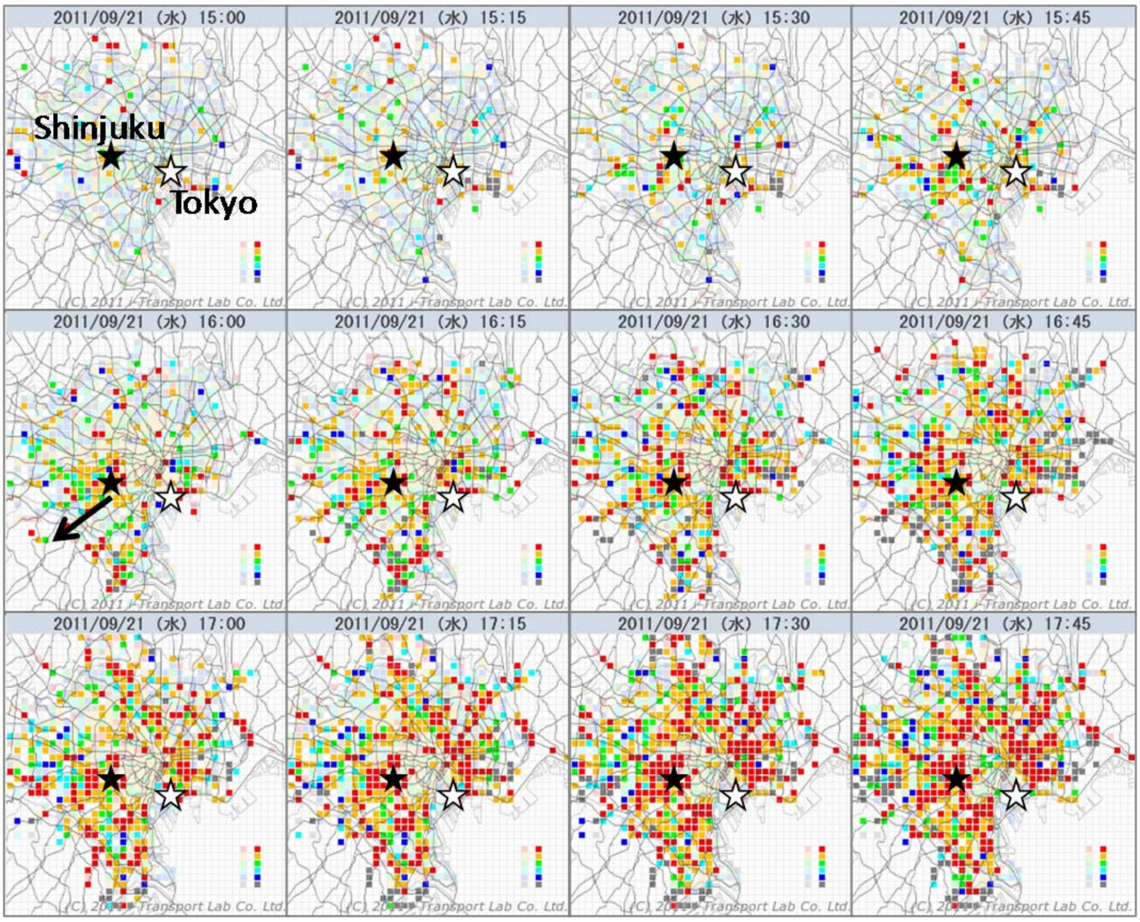

Figure 5: Tokyo Traffic Scope (the biggest peak)

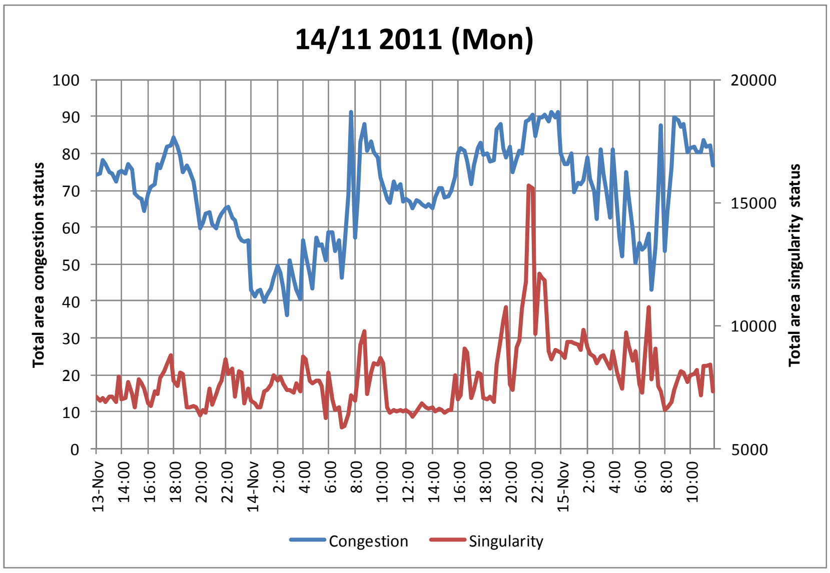

Figure 6: Changes on the total fluidity and the total singularity in Tokyo city centre (the second peak).

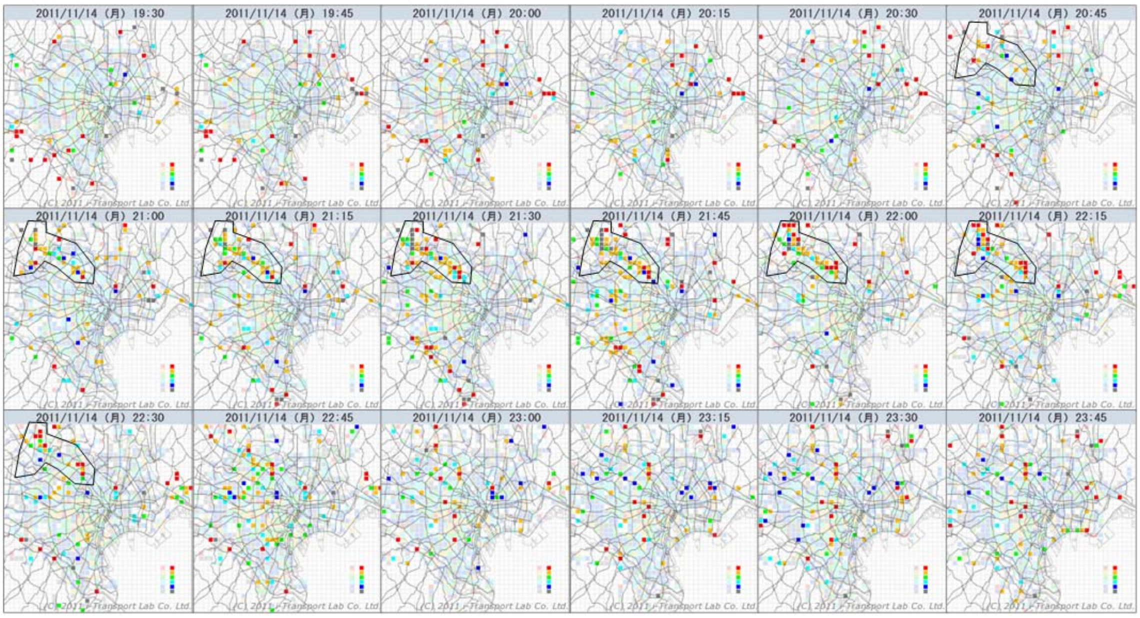

Figure 7: Tokyo Traffic Scope (the second peak).

CONCLUSIONS AND FUTURE WORKS

In this paper, we have introduced the concept of the Traffic Scope based on the aggregated traffic conditions for mesh-wised area with FCD. The Traffic Scope consists of two indexes, the fluidity to quantify the smoothness of area traffic flows, and the singularity to highlight anomaly traffic conditions. For the purpose of incident detection on surface streets, we have proposed the methodology to monitor the total amount of the singularity index in the subject area. Through the preliminary study by using the FCD in Tokyo city centre, we have found some cases to validate the detection methodology. The listed items below are the future works;

- find the effective threshold for detection
- automatic focus on the specific area affected by the incident
- reasoning on the cause of the congestion

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