VISUAL EXPLORATION OF SPATIAL-TEMPORAL TRAFFIC CONGESTION PATTERNS USING FLOATING CAR DATA

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OVERVIEW

- Motivation
- Background and State of The Art
- Test data
- Visualization methods
- Result and Analysis
- Conclusion

Motivation

- Traffic congestion → big issues in traffic management
- Solution → explore traffic patterns
- Several data sources for traffic monitoring → cctv, inductive loop, fcd
- Floating car data → reliable data source for traffic information

Research Goal

Visual exploration of traffic congestion patterns in spatial and temporal dimension.

- When
- Where
- How long

Background

- What is traffic congestion? Classification of traffic?

  Traffic Congestion :

    Road volume > Road capacity

  Classification :

    Recurrent traffic congestion

    Non-recurrent traffic congestion

  Identified by :

    Speed, Travel time, Density

Background

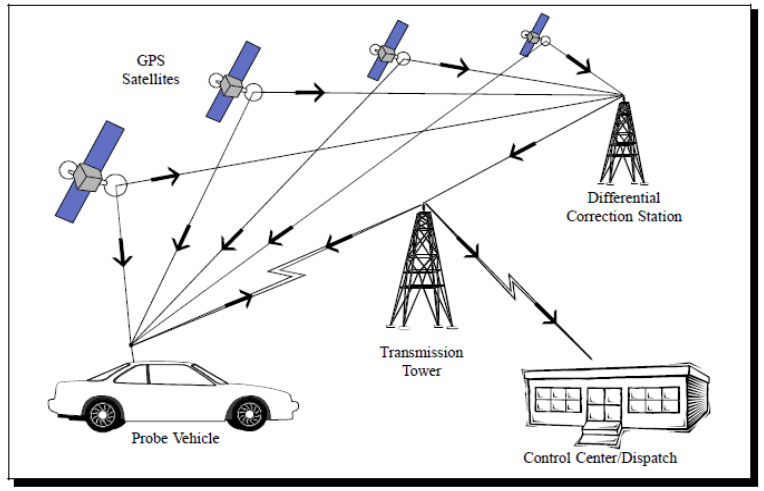
- What is floating car data? How to get it?

  Floating Car Data :

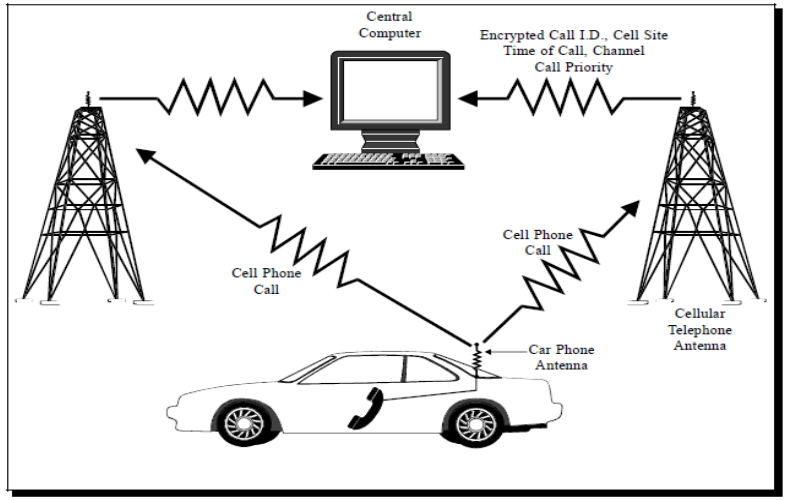
  Collect real-time traffic data from vehicles

  Methods :

FCD based on GPS systems

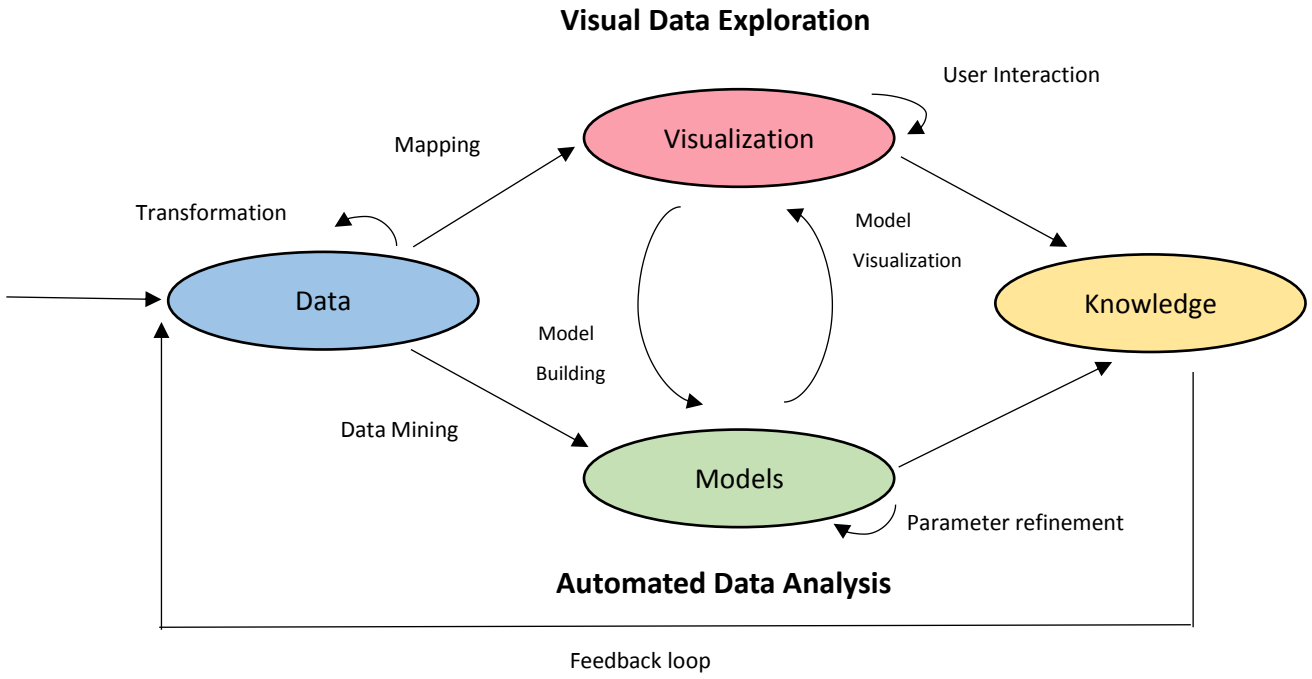


FCD based on cellular phones



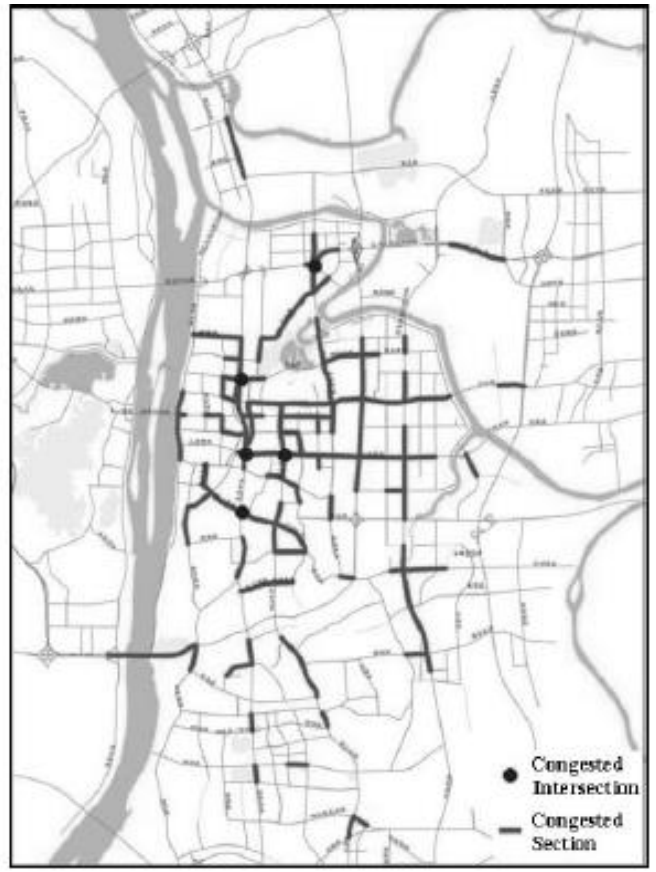
State of the Art

- What is visual analytics? Data mining and visualization?



Related Works

1. X. Liu, et al (2012) used FCD data from 6000 taxis in Changsha city to detect urban traffic in road network by using ‘road joint_road section_zone’ model. As a result, 12.7% roads are in heavy congestion degree which mainly concentrated in center zone, 8.00 – 8.15 AM is the morning peak and 17.45 – 18.00 PM is the evening peak hour.



Related Works

2. Lin Xu, Yang Yue and Qingquan Li (2013) proposed a FCD analysis method for congestion exploration based on data cube by using FCD dataset from about 1,200 taxis for one week.

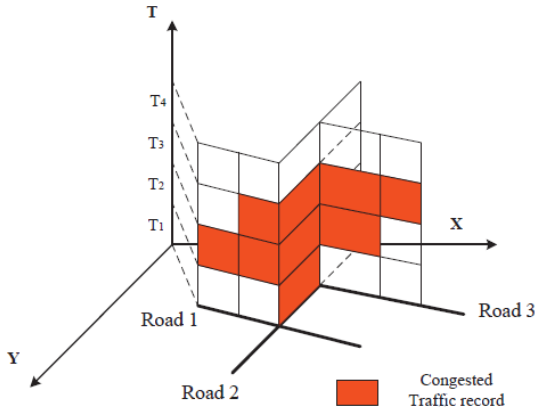
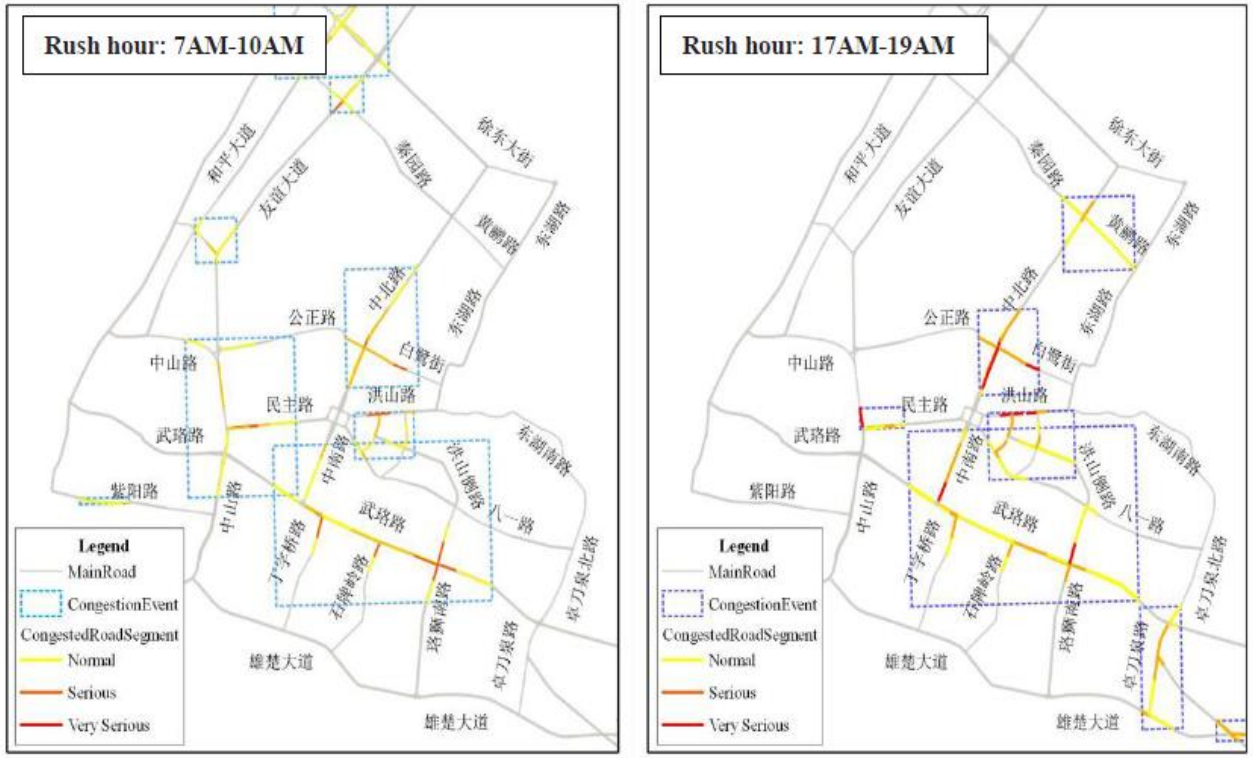


Figure 2. Spatial-temporal related record in congestion

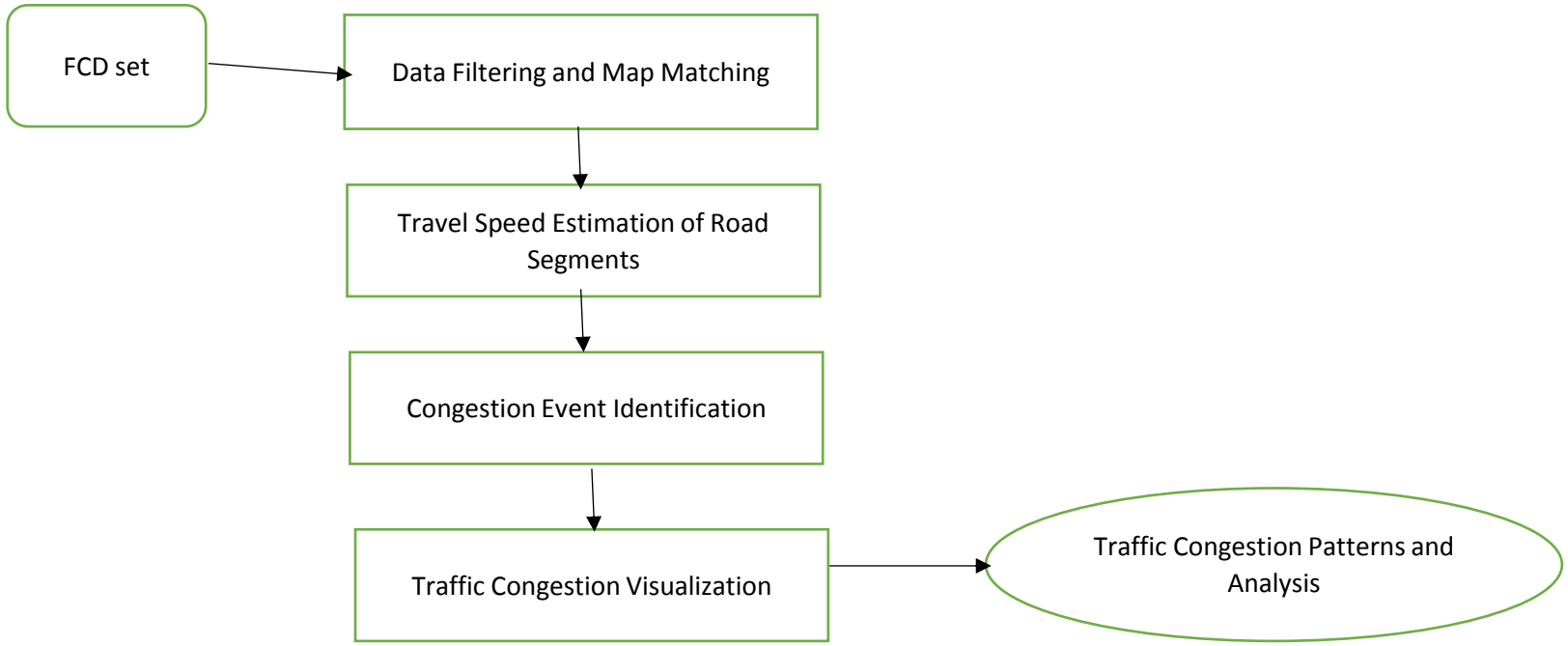


a. Rush hour at morning

b. Rush hour at evening

Methodological Framework

General Workflow



Test Data

- Study area (Shanghai)

Test Data Set

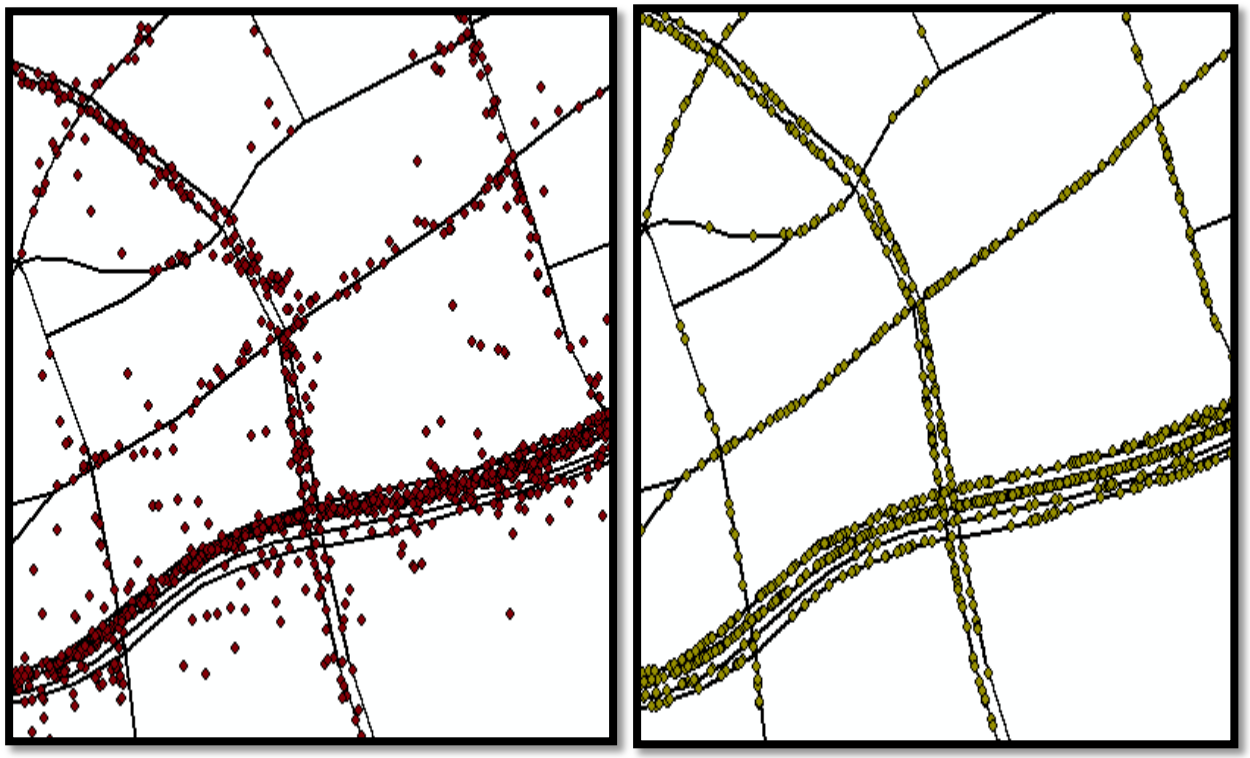
Fieldname	Field Value	Details
Date	20100617	8-digits number
Time	230717	6-digits number
Car ID	11692	The unique ID of the taxi, 5 digits
Company Code	QS	Initials of the taxi company
Driving Direction	6	Direction in 2 digits
Longitude	12.161.365	in degree; accurate to the 6th decimal place
Latitude	31.201.005	in degree; accurate to the 6th decimal place
Instaneous Velocity	34.9	accurate to 0.1 km/h
Instaneous Altitude	255	accurate to 1 m
Car Status	0	0 for empty; 1 otherwise
GPS Effectiveness	0	1 for effective; 0 otherwise
Record Time Stamp	17-06-2010 23:07:17	In form of YYYY-MM-DD hh:mm:ss

Pre-processing of FCD

→ Filtering

FID	Shape *	Date	Time	Car ID	Instant Ve	Car Status
1052	Point	2010000	17003723	10389	9,9	0
1053	Point	2010000	17101043	15404	7,5	1
1053	Point	2010000	17111522	15980	6,6	0
1054	Point	2010000	17150541	14840	8,5	1
1054	Point	2010000	17151318	10944	8,1	1
1054	Point	2010000	17160301	15012	7,9	1
4248	Point	2010000	17171638	15819	9,9	1
6484	Point	2010051	17254549	14095	9,5	0
1471	Point	2010000	17180307	12776	6,5	1
1471	Point	2010051	17185142	10450	7,9	1
1471	Point	2010000	17210023	14045	8,2	1

→ Map matching

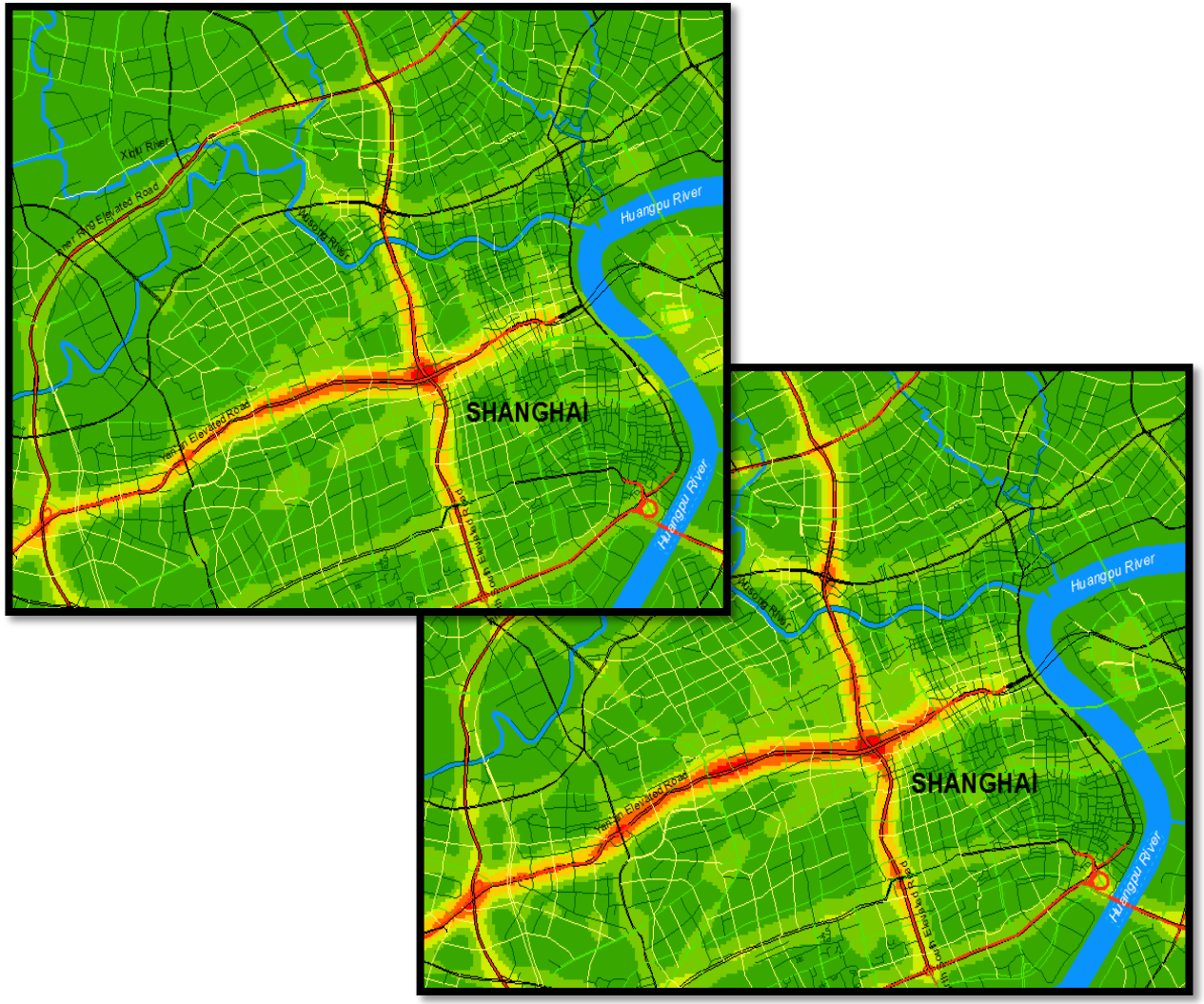


Point Density Mapping

Density estimation by using Kernel Density Method

$$\hat{f}_h(x) = \frac{1}{n}\sum_{i=1}^{n} K_h(x - x_i) \quad = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right)$$

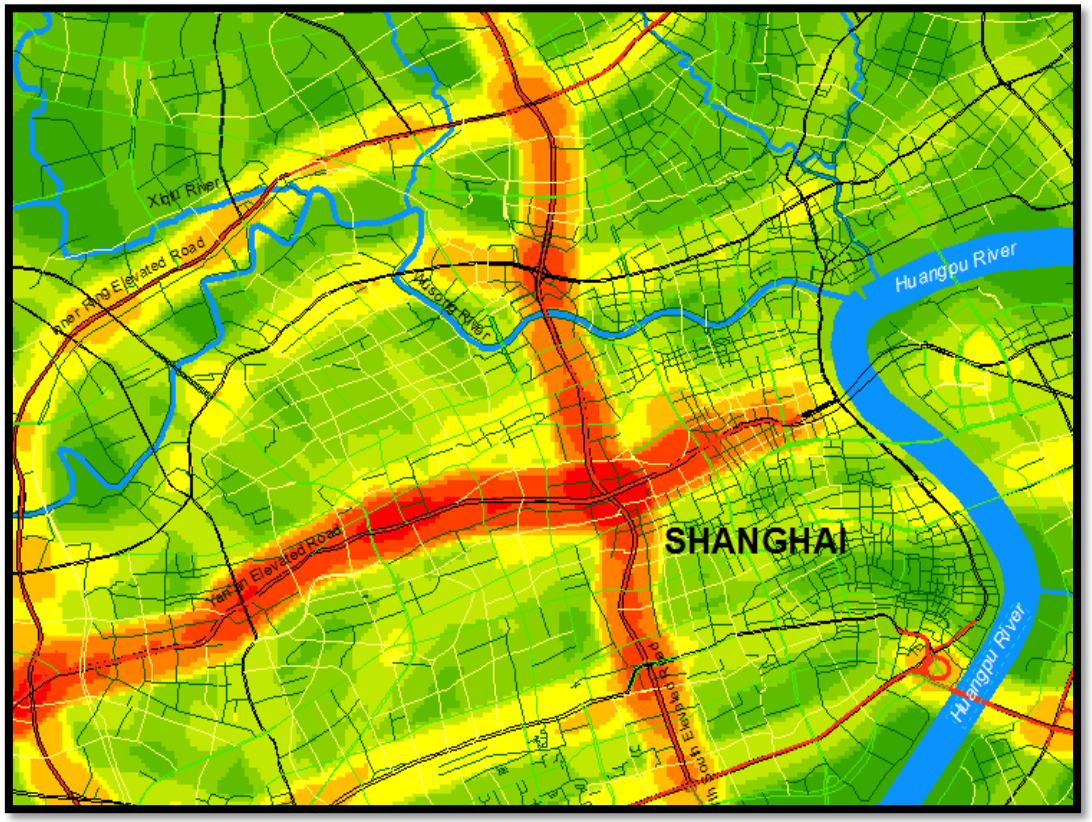
GPS points density is calculated based on the instaneous velocity with search radius 20 meters.



Line Density Mapping

Line-density method is used to determine the frequently used road segment.

Trajectories from each taxi are used to calculate the line density with search radius 20 m.



Density Mapping Analysis

- From the result of the point density mapping, the highest density are mostly in the elevated roads/expressway.
- The frequently used of road segment are also on the expressway/elevated roads.

Density Mapping of Stop Taxis

Clustering for stop taxis is used to visualize the stop taxi patterns.

GPS points which have instaneous velocity less than 5 km/h are used.

Only taxis which have passengers are used.

Grid base clustering is used.

Visualization of traffic congestion on road network

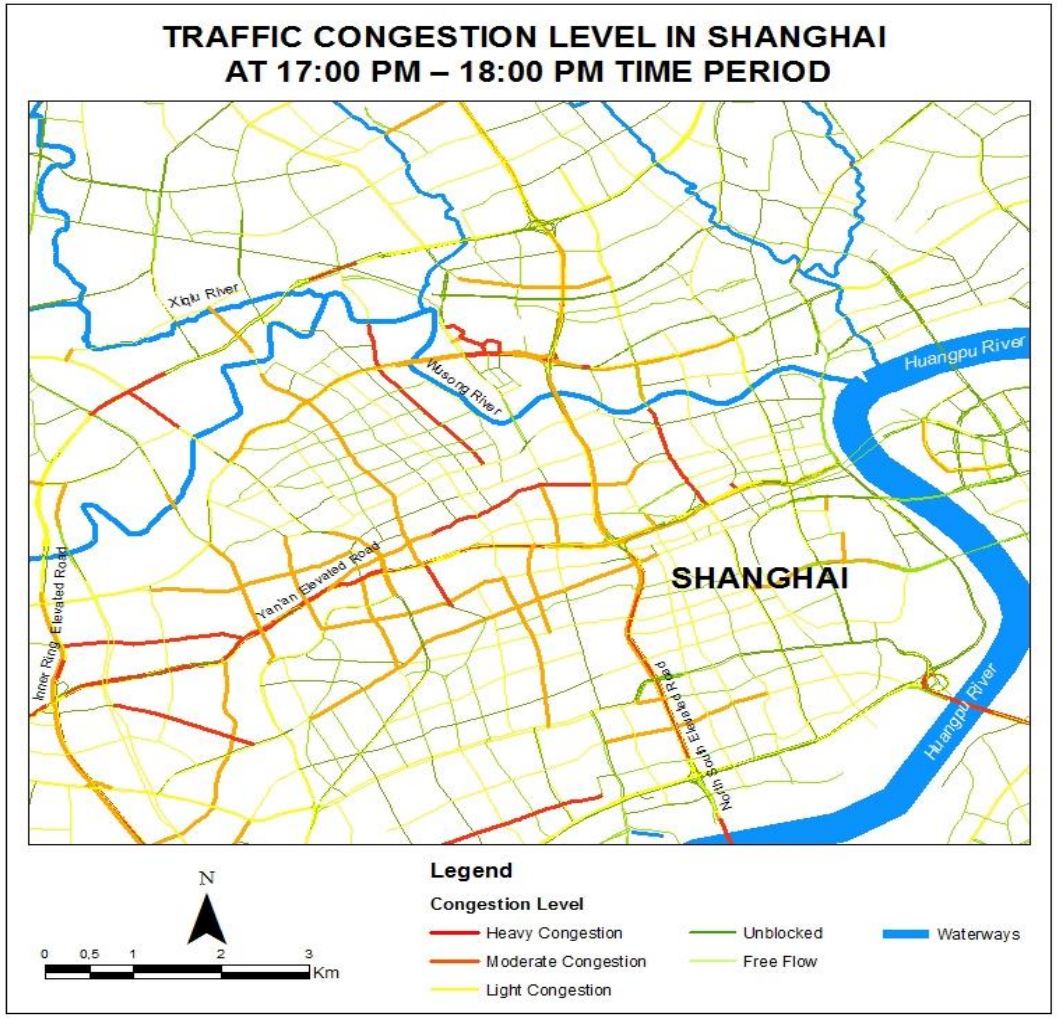
Identification of traffic congestion is based on the travel speed, and classify by using classification proposed by Duan, et al (2009)

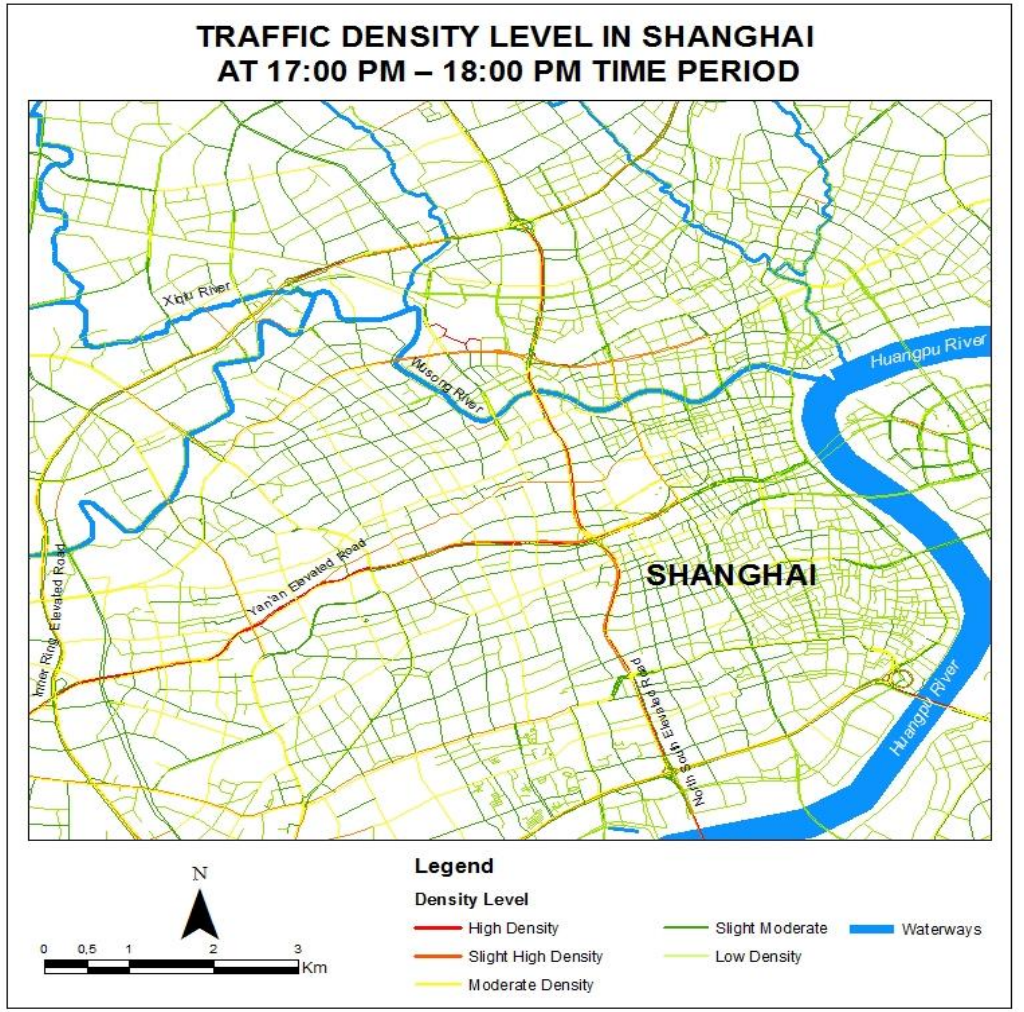
Road type	State 1	State 2	State 3	State 4	State 5
Elevated road	< 20	20 - 35	35 - 55	55 – 75	> 75
Expressway	< 20	20 - 30	30 - 40	40 – 75	> 75
Main arterial road	< 15	15 - 20	20 - 25	25 - 40	> 40
Arterial road	< 15	15 - 20	20 - 25	25 - 40	> 40
Collector road	< 13	13 - 18	18 - 23	23 - 33	> 33
Branch road	< 13	13 - 18	18 - 23	23 - 33	> 33

For each road segment, the GPS points which located near the road segments were aggregated to calculate the mean speed to identified the congestion and to calculate the duration of congestion.

Visualization Methods

Visualization of traffic congestion on road network





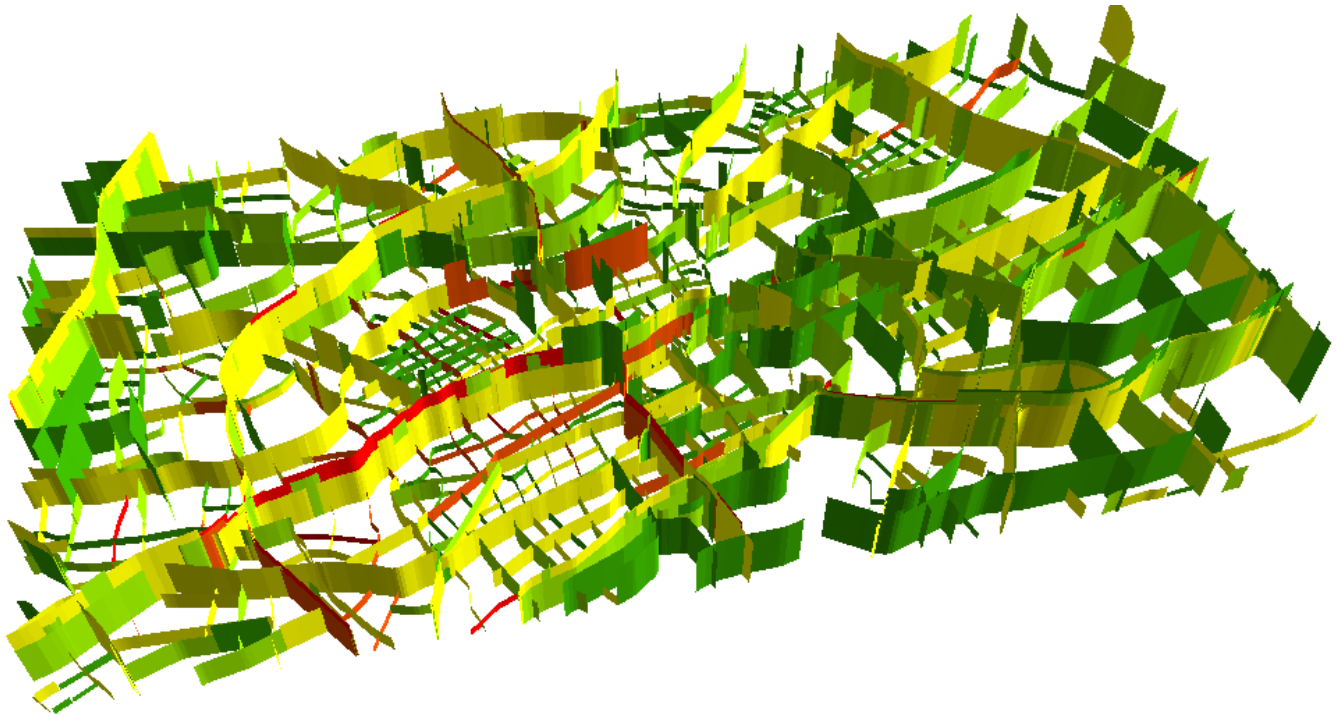
Analysis of Visualization on Road Network

- Congested roads could be easily pointed on the map by using different color for each level.
- The distribution of congested road and high density taxis in spatial dimension could be easily depicted on the map.
- The heavy congested roads also have the highest density of the taxis.

3D visualization by Using Extrusion Graph

Using the data from the traffic congestion visualization on the road network.

Different color is used to differentiate the level of congestion, and the height is used to visualize the average velocity.



Analysis of 3D Extrusion

- By using this visualization, the differences between each level of traffic congestion will be shown clearly by using different color.
- Interesting pattern between traffic congestion level and average velocity could be extracted, which is the highest the average velocity the lowest probability the road will be congested.

Animation using Time Slider

Using sequential maps from the result of traffic congestion on the road network.

It shows temporal changes of the traffic congestion events.

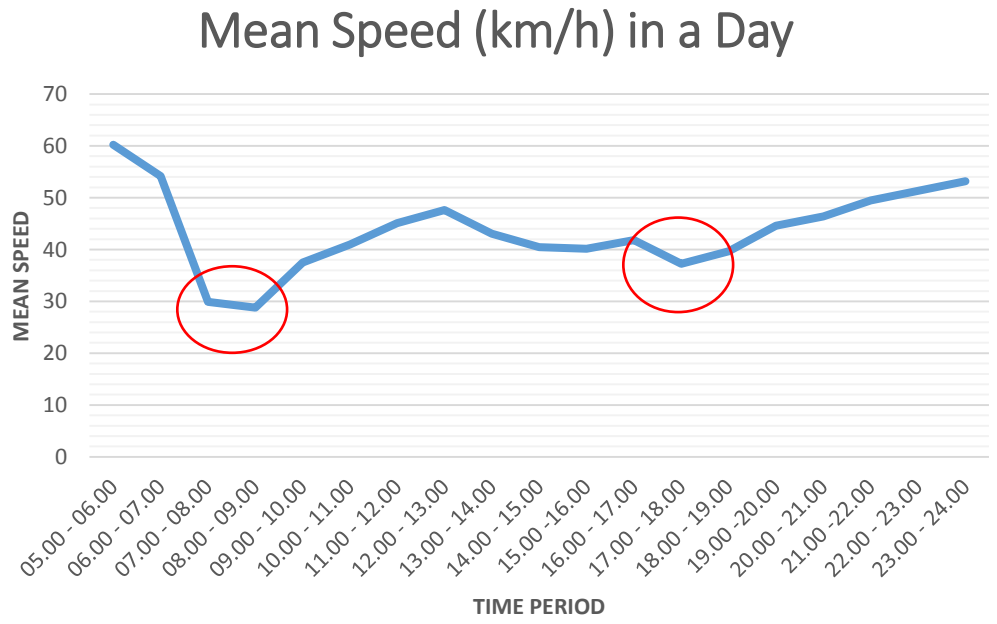
Analysis of Time Slider Animation

- From time slider animation, the changes of the traffic congestion events on the road network could identified for different time interval.
- Some part of road segment remains the same for different time periods, such as a part of road segment in Yan’an Elevated Road with heavy congestion level.

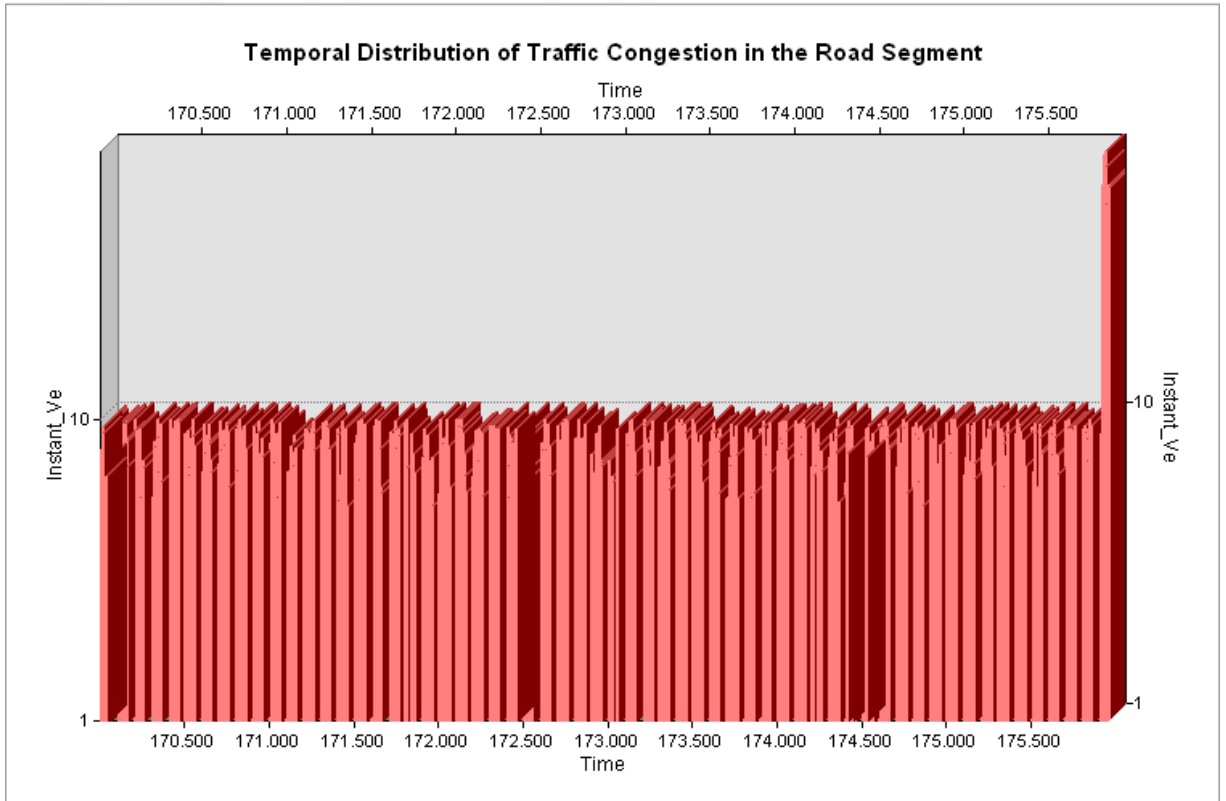
Result and Analysis

Temporal analysis

- When the peak of traffic congestion?



- How long?



Result and Analysis

Spatial Analysis

Type	Traffic Events	Percentage
Expressway/Elevated Road	1009	34,22659
Main Arterial Road	1464	49,66079
Arterial Road	238	8,07327
Colector Road	237	8,039349

- Traffic congestion mostly occurs in the expressway/elevated roads and the main arterial roads.
- The Yan'an Elevated Road and North South Elevated Road have the most frequent traffic congestion.
- The Yan'an Elevated Road and North South Elevated Road which have the highest density are also have the most frequent traffic congestion.

Result and Analysis

Spatial Analysis

- Stop taxis clusters mostly located near the intersections or in the congested roads which shows stop and go traffic patterns.
- The higher the average velocity, the lower the probability of traffic congestion.
- Density Mapping and Visualization of traffic congestion on the road network helps to identify traffic congestion in spatial dimension.
- 3D extrusion graph could be used to visualize two different attributes of the data in the same time window.
- Animation with time slider could be used to identify changes of the traffic congestion events in both spatial and temporal dimension.

Conclusion

- FCD is a very useful data source to derive information about spatio-temporal pattern of traffic congestion in the city area.
- Density Mapping and Visualiazation on the road network methods are more suitable to visualize the traffic congestion on spatial dimension.
- 3D extrusion graph is used to visualize and emphasize two different attributes in the same time window by using coloration and height.
- Time slider animation is used to show changes of the traffic congestion events both in spatial and temporal dimension.
- Map-matching and clustering techniques, a suitable time ranges, classfication ranges and visualization methods should be chosen wisely so that the results could really represented the actual condition of the traffic congestion.

Questions?