Real-time safety alerts for severe weather and jam tails

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1. Abstract

We present a technology to derive and report the impact of the current weather conditions on real-time road congestion, using TomTom floating car data. This technology enables the creation of accurate alert messages on weather related congestion and accurate prediction of the location of jam tails. The alerts are provided to connected navigation devices and road authorities to provide safety alert messages at the right time to the impacted drivers on the road.

2. Introduction

Unexpected traffic jam tails and severe weather conditions are among the most common causes of road accidents. The majority of drivers have experienced situations where sudden changes in speed or weather conditions have resulted in dangerous situations. Long term statistical analysis indicates that 23% of car crashes in United States are weather-related [1].

Our challenge is to automatically provide reliable safety alert messages derived from floating car data and real-time weather polygons. It is absolutely critical to deliver these messages with great accuracy to the right driver at the right time.

Floating Car Data has become an increasingly important and reliable source to derive congestion information [2]. However, accurate delivery of alert messages at the right time and location remains a challenge. The availability of highly accurate floating car data and weather data now allows for detailed analysis on these dangerous road situations. By analyzing an extensive collection of floating car data and correlating this data to real-time weather information we have derived a speed adaptation model. The model predicts the impact of severe weather conditions on the actual driving speed on the road. The model can thus be used to combine weather and traffic information to provide accurate alerts to the driver.

On top of this, the detail currently provided by floating car data allows for accurate prediction of the position of the jam tail, the location where cars are most likely to collide. Our analysis shows that in many cases we can accurately predict the tail of a traffic jam and if needed provide the current weather conditions as additional information to the driver.

The derived weather and jam tail alerts are subsequently delivered to car drivers on their navigation device. Whenever the driver approaches a traffic jam with high speed, the device alerts the driver to slow down. In areas with bad weather and heavy traffic, the driver receives information on traffic jams that are likely to be impacted by the weather. In addition to the common delay information the alert will contain information on the type of weather (snow, rain, …).

Aside from direct delivery to the navigation device, a service has been set up to deliver the alert messages as direct data stream to road authorities or governments, who can alert drivers over common communication channels like websites, radio and dynamic traffic signs on the road. A map view of alerts can be used for traffic and safety monitoring in traffic control centres.

3. Floating Car Data

3.1. Data Collection

TomTom generates real time traffic information by combining measurements of existing infrastructure with signals from anonymous TomTom GPS devices, connected cars and GPS equipped smartphones. All the devices that are connected to TomTom Traffic keep track of their own location and send this data back to TomTom every few minutes. Also known as Floating Car Data (FCD) this community feedback provides a unique source of information, giving insight in all the roads in the network. As shown in Figure 1, the following sources contribute to TomTom Traffic:

- GPS Data from TomTom Portable Navigation Devices with connected services
- GPS Data from TomTom Smartphone navigation applications
- GPS Data from TomTom Fleet Management systems (also known as TomTom Telematics)
- GPS Data from 3rd party GPS enabled Smartphones
- GPS data from in-car systems (both TomTom and 3rd party GPS systems)
- Public Traffic Information, based on traffic sensors, road camera's and journalistic data related to road works and traffic incidents

Figure 1. Sources for TomTom Traffic

Additionally TomTom's historical traffic data is used as a background source which allows the system to detect anomalies in the traffic situation and compare current observed speeds to expected speeds.

To derive high quality traffic data TomTom uses innovative techniques to compensate for differences between sources, combine different data transmission methods and apply proper quality assurance. Information from all these sources is automatically filtered and combined to generate real-time traffic information. In this way thousands of data points are received each second and processed to derive the current traffic state on a global scale, updated every 30 seconds.

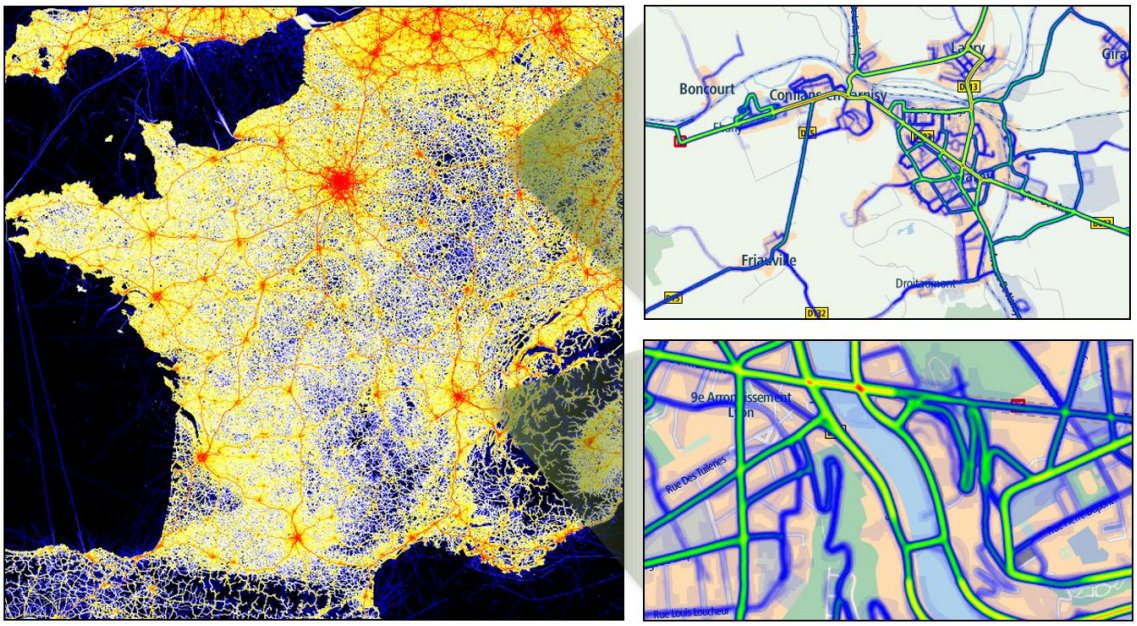

Figure 2. Floating Car Data is collected on all roads with GPS equipped cars. Left: all GPS traces collected in France over one quarter. Right: Enlarged view on two different regions with trace data overlaid on a map. The density indicates the amount of data collected for each road.

3.2. Characteristics of FCD

Using Floating Car Data from various sources provides a number of benefits compared to other ways of measuring travel time and speed information. First of all, Floating Car Data do not depend on the availability of road side equipment, such as measurement loops, Automatic Number Plate Recognition (ANPR) systems or Bluetooth sensors.

TomTom is able to measure travel time and speeds on all accessible roads and do so accurately in all instances. The density of the collected data increases automatically with the number of vehicles on the road. This characteristic is clearly visible in the visualization of the FCD data in Figure 2. As a result, the measurements are most accurate when the information is needed the most: during congestion.

The TomTom map matching process enables the system to accurately report speed information even on roadways that are under construction. Additionally the TomTom system is able to report traffic information on newly opened roadways, directly when the road has been added to the TomTom map database.

The use of Floating Car Data is especially advantageous in slow traffic conditions when it can take a long time for a single vehicle to traverse the entire road section. As TomTom GPS devices collect location measurements once every second, changes in speed can be detected quickly and located precisely, even when they happen at any location between the beginning of the road section and the end of the road section.

4. Jam detection

When enough probes contribute to the system, FCD allows for highly accurate detection of congestion. Figure 3 displays a few hours of anonymized FCD data for a certain road section. The color indicates the speed derived from each individual trace. This time-distance plot clearly visualizes the drop in speed on this road during a certain period of time. The traffic jam is detected by when a significant amount of individual reports indicate a strong reduction in speed. When the speed drops below a certain threshold, and there is a significant impact on the traffic flow a traffic jam message will be created.

These jam warnings are sent out by TomTom to all the users of the TomTom Traffic feed, which can be individual users of navigation devices, connected cars, fleet solutions or road authorities. Road authorities can directly use this information to plan an optimal route or derive appropriate road side messaging.

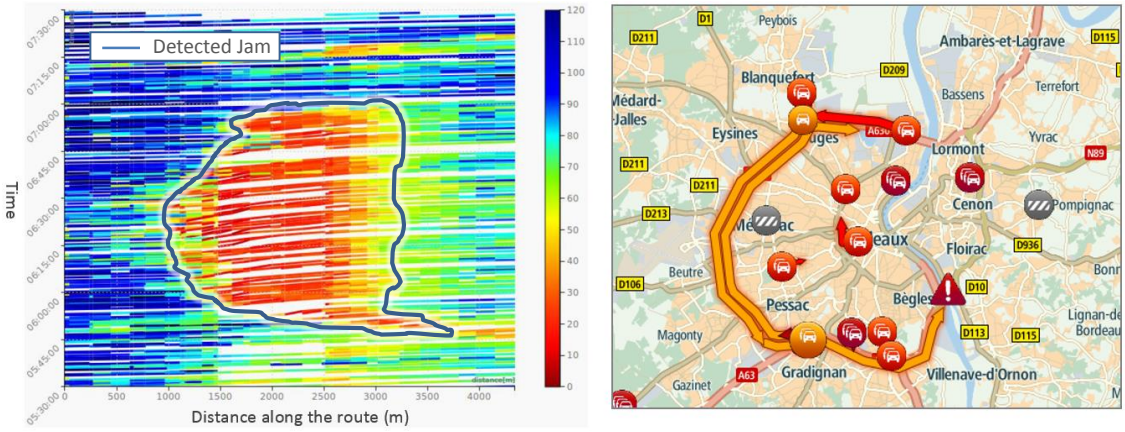

Figure 3. Left: GPS probe data for a selected route over 2 hours in the morning. The color indicates the derived speed. Based on the aggregated information from multiple probes the location and duration of traffic jams can be accurately detected. Right: Every 30 seconds traffic jams are published by TomTom to all the subscribed users.

5. Severe Weather Warnings

5.1. Weather Information

TomTom collects different types of weather input data from third-party content providers and processes this data into localized, traffic-relevant weather information. The data for the precipitation polygons is collected from local radar stations with a resolution of 2x2 km and updated at a 15 minute interval. In Figure 4 the precipitation radar data is represented as polygons with different color intensity to specify the severity of the precipitation. The following weather types are distinguished:

- Rain
- Snow
- Mixed (combination of snow and rain)

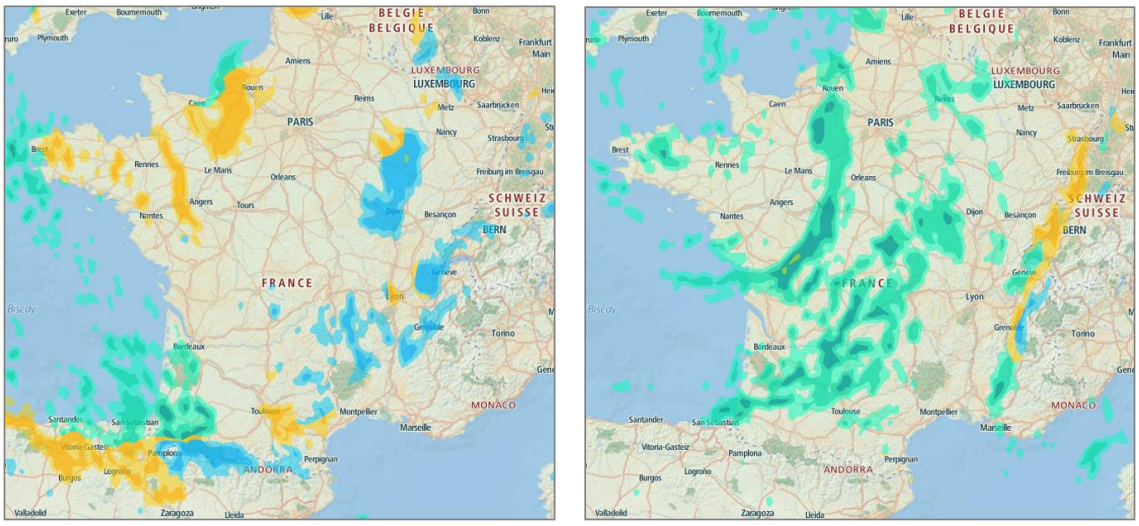

Figure 4. Precipitation polygons displayed over the map of France. The color indicates the type of precipitation (Green=Rain, Blue=Snow, Yellow=Mixed) and the density, where dark areas have more heavy precipitation.

This weather data is used to derive traffic messaging where congestion is likely to be caused by the precipitation. When a speed reduction is observed based on FCD and the jam is also covered by a precipitation polygon, a warning message is created that indicates both the speed and the cause of the congestion.

To estimate whether the jam is caused by the weather conditions, the stop-and-go behaviour of individual vehicles is analysed. The driving pattern shows clear differences between regular traffic jams and slow traffic caused by precipitation. The models have been trained to recognize this driving behaviour so that weather messages are only created when the weather is actually impacting the road conditions.

5.2. Speed Adaptation Model

Deeper analysis of the relation between historical traffic traces and precipitation polygons has resulted in a *speed adaptation model*. This model accurately predicts the driven speed on the road for a certain precipitation type. Figure 5 shows the derived impact of light rain and heavy rain on the driven speed. It shows that the speed adaptation depends on both the speed and severity of the precipitation. As expected, heavy rain will cause slower traffic. Another observation is that the relative impact increases for higher speeds. For minor roads rain has limited impact on the speed, while roads with an average speed of 120-130 km/h show a relative reduction of the average speed up to 12%.

When precipitation has stopped, the road conditions might still not provide optimal driving conditions. When low speeds are observed after heavy snow we will anticipate that this is caused by the persistent road conditions and still report that the speed reduction is caused by snow.

The precipitation polygon data also contains forecasting information up to 75 minutes in the future. This information is used to predict the development of the traffic conditions over the next hour. In this way the TomTom Traffic service is able to indicate for each traffic jam whether the congestion is increasing or decreasing and when the traffic jam might be dissolved. This information is especially useful when planning a longer route or for logistics optimization when the optimal time of departure needs to be determined.

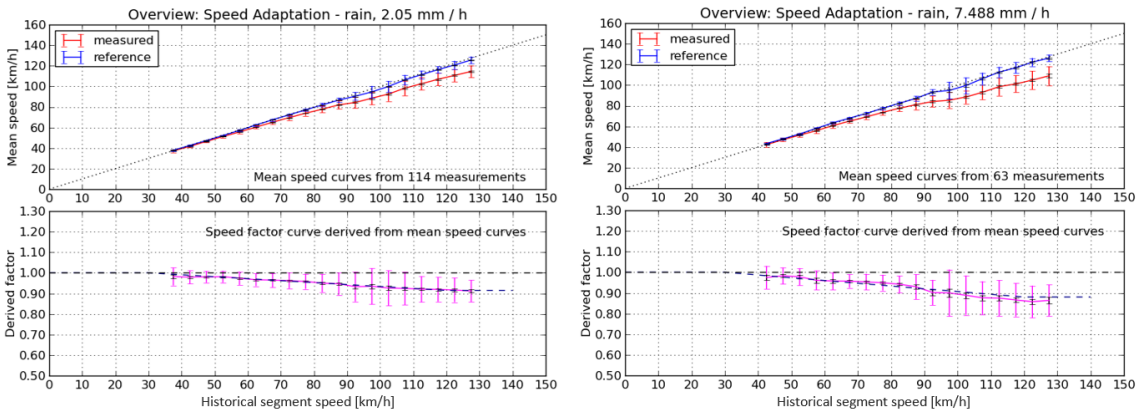

Figure 5. The precipitation-speed adaptation model. Left: speed adaptation for light rain (2.0 mm/h), the red line indicates the average observed speed reduction compared to a measured reference speed. The bottom plots show the derived speed reduction factor. Right: speed adaptation for heavy rain (7.5 mm/h), which shows an average reduction of around 12% on the higher road classes.

6. Traffic Jam Tail Warnings

6.1. Jam Tail Detection

Traffic accidents occur for many different reasons, but a large number of severe accidents are caused by vehicles driving into the back (tail) of a traffic jam. Depending on the type of vehicle driving into the traffic jam, the impact can be catastrophic.

To warn users about this kind of situations, TomTom developed a 'Jam Tail Warning Service'. This service provides the location of the tail of the traffic jam and the speed of the traffic on all motorways where the TomTom Traffic service is available. Based on these details drivers can be accurately informed and provided with advice on their driving speed.

To create a jam tail warning message, multiple factors are taken into account. First the exact jam location is estimated as described in Section 4, but now also very short but severe speed reductions are taken into account. The absolute speed in the rear part of the traffic hold up is determined by looking at the road segments in the last few hundred meters of the jam. When the observed speed is below a fixed threshold, the speed drop is derived by comparing the speed of the cars that approach the jam to the speed in the jam tail. When a dangerous speed reduction is observed a warning message is created at the location of the jam tail.

The location of the jam tail is known to move upstream on the road in the initial stage of a developing congestion [3]. This is also the most dangerous period as the drop in speed observed by the driver is most prominent. Therefore a warning is created in the current service only for jam tails moving upstream. On top of this the progression of the tail location is extrapolated to give the best estimation of the tail location for the next driver approaching the jam.

6.2. Jam tail hotspots

Monitoring the jam tail locations over a period of time gives us another interesting insight into the traffic conditions on the road. Figure 6 shows a heat map of the most frequent locations where jam tails warnings are given on the ring road around Brussels. This heat map is based on two weeks of collected data, where the location of each jam tail warning has been stored. Alternatively a similar analysis could be done to find the most dangerous locations for a certain period of time during rush hour or a specific day of the week.

The most dense locations indicate the locations where jam tails occur almost every day. Zooming in on the western junction we can see that we can accurately pinpoint the most problematic spots. For example, the north-bound road shows a clear cluster of jam tail warnings right before the exit towards the city center.

This analysis gives a direct indication of some of the most dangerous locations on the motorway. It could therefore be used by road authorities to focus improvement plans or place dynamic warning signs.

7. Message delivery

Accurate and timely delivery of traffic warning messages is essential for any application relying on this information. The TomTom Traffic messages are updated every 30 seconds and delivered over the air either directly to the driver or as a data feed to companies and governments.

Figure 6. Left: A heat map of the most frequent locations of jam tail warnings around Brussels. Right: The dots on the road indicate the exact position of jam tail warnings, which allows to accurately pinpoint the most dangerous locations on the motorway.

The navigation application, whether integrated or on a portable device, is the most optimal channel to communicate traffic information directly to the driver. Figure 7 shows the implementation of jam tail warnings and weather alerts on the TomTom software. Jam tail warnings are only provided when a dangerous situation is likely to occur for the driver. Based on the current speed of the vehicle and the location of the jam tail the navigation device is able to determine whether a warning message is needed.

Other channels that can be used to reach the driver are radio and road signaling. TomTom provides the warning messages in a data feed that can be integrated in any other service. This allows radio stations to extract the most urgent weather related traffic jams or road authorities to place warning signals at the locations where frequent jam tails occur.

Future solution will be able to actively take the forecast of weather messages into account. By predicting the impact of severe weather on the upcoming road conditions a personal navigation service can decide to route the user around a snow storm where possible.

Figure 7. The TomTom navigation software already alerts drivers when they approach a jam tail at high speed. Weather messages are given when the congestion is likely to impact the journey of the driver.

8. Conclusions

Providing better information to drivers, emergency services and road authorities is one of the key steps to safer roads. We have shown that floating car data can effectively be used to derive real-time traffic warning messages. There is a clear correlation between severe weather conditions and traffic congestion, which is used by TomTom to create a real-time feed with severe weather messages that can be monitored in a traffic control room or sent directly to the driver. Precise detection of the tail of the traffic jam enables real-time warnings for drivers approaching a traffic jam at high speed. Next to that, a statistical analysis of these locations can be used to detect the most dangerous locations in the road network as a recommendation for permanent infrastructure improvement.

9. References

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Biography

Maarten Clements
Senior Pre-Sales Engineer Geospatial, TomTom

TomTom Geospatial leverages TomTom's wealth of content in order to deliver fresh and high-quality digital maps and services to a wide range of customers, from leading internet companies to governments and enterprises.

Within TomTom Geospatial, Maarten is the product expert for the full portfolio including Maps and Traffic, supporting pre-sales activities across Europe. With a Ph.D. in information science and over 5 years of experience in TomTom, Maarten has a deep understanding of big data products and the underlying algorithms that turn rich data into solutions.

Nick Cohn
Senior Traffic Expert, TomTom

Advising businesses, governments and policy-makers on new solutions to global traffic congestion problems. One of his missions is to help road authorities and other mobility partners make the transition from traditional traffic management methods to more modern solutions that make use of probe data and traveler connectivity. Nick's current focus is on helping cities to become smarter, through the use of TomTom data and maps – as well as making autonomous driving a reality.

He was educated at the University of Washington and University of Pennsylvania on Economic Geography and Regional Science and has 25 years of experience in travel behavior and transportation.