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THE M4 HIGHWAY

The Russian M4 highway links Moscow with the Black Sea coast, and in particular with Krasnodar, Rostov and Novorossiysk. The latter two are large port cities on the Don River and hence the name “Don” for the highway. This “artery” connecting Moscow with Southern Russia is a major expressway with a length of 1517 kilometers.

During a decade of economic boom starting in 1998, traffic on the highway also grew, with congestion becoming a problem. To address this issue the Don Road was extensively upgraded and widened in the 2000s–2010s into an expressway. Nowadays the road suffers from heavy traffic congestion caused by summer vacationers travelling to the Black Sea resorts and by trucks transporting goods from the southern provinces to the heavily populated areas of Central and Northern Russia.

Considering such challenging traffic properties it becomes extremely important to have an incident detection system that is able to automatically detect traffic abnormalities and report them to the operator in the control center. Each traffic abnormality represents a potential danger for highway users and prompt reaction from an operator is necessary to warn them. Ideally the system should detect all abnormalities and raise zero alarms when no abnormalities are present on the road. A popular approach for automatic incident detection is video-based incident detection, since it can rely on same cameras that operators use to control the traffic. However, video-based automatic incident detection on highways is difficult because it needs to be robust to all weather conditions, illumination changes and other environmental properties. This poses a great challenge to video-based incident detection with respect to high detection rate and low false alarms requirements.

This document describes some key points of Telegra’s X-AID™ video-based automatic incident detection system, which was installed as a pilot project on selected cameras on the Don Highway. To make this document concise and up to the point only the most important observations about challenges successfully tackled by X-AID™ are described. There are, however, many more.

X-AID™ - A CUTTING EDGE VIDEO-BASED INCIDENT DETECTION TECHNOLOGY

When it comes to recognizing incidents on the roads or in tunnels, automatic video incident detection is of vital importance. Many users adopt this technology due to its instantaneous incident detection abilities. Also, a complex set of incidents can be detected. However, lately, with advances in computer vision technology that are now implemented for everyday use (advanced driver assistance systems, for example), traditional video-based detection systems are facing harsh criticism due to their low detection reliability and high number of false alarms.

- 95% detection rate
- 0.72 false alarms per camera per day
- Immune to image variations caused by environmental conditions (sunlight, rain, low light)
- Resistant to Artefacts caused by shadows
- Works with low quality image
- Not affected by rain drops on camera
- Detects during low visibility and camera noise
Examinining the weaknesses of traditional systems, Telegra’s X-AID™ sets its own criteria and goals for video-based incident detection. In order to achieve high accuracy and low level of false alarm rate following important steps and actions are taken during work of algorithms:

- Separation of moving objects from the background. Background image is updated dynamically so that the system is able to adapt to changes in the background.
- Vehicle and pedestrian detection. In this step moving objects are tested against set of rules (learned in the training phase) to identify whether the moving object is pedestrian, vehicle, or some other objects. Using an advanced pattern recognition technology non relevant moving objects (e.g. shadows) can be excluded from further analysis.
- Object tracking. In this step objects are tracked through the region of interest, so that the system is aware of their position at all times.
- Incident detection and statistics gathering. In this step incident detections is performed and statistics are gathered by examining objects’ trajectories and other relevant data provided by X-AID™ algorithms.

Detection of following incidents is supported by X-AID™ in the M4 pilot project: stopped vehicles, congestion, wrong-way vehicles, pedestrians, slow vehicles and debris on the road. Few of the many technical challenges while detecting these incidents on the open road are illustrated below.

### 2.1.1 Image variations caused by environmental conditions

Traditional video-based incident detection systems typically observe changes in image sequence over time. This may create a lot of issues if pixels intensities vary through time as a result of conditions unimportant for traffic analysis. Making the detection system robust to such image variations becomes even more important for outdoor usage since image variation can be caused by environmental conditions (transitions from sunny to overcast weather or transitions from day to night, for example). Trying to separate objects of interest from the static background image, which models an image without any objects of interests, becomes difficult without additional “intelligence”. This is where pattern-based pedestrian and vehicle detection with tracking comes to aid.

Below images illustrate an example of frequent temporal variations due to weather conditions. In the top left image sun reflection is not present on the road. The time point here is just before the arrival of the red vehicle shown in the top right image. When the red vehicle arrives the sun reflection is visible only in the upper segment of the picture. Just before the vehicle stops, again, sun is not visible on the road, as shown in the bottom left image. The bottom right image shows the time point when the vehicle is detected as stopped. Here, sun reflection is visible on almost half of the image.

There are many situations that can be classified into this category of challenges. Here, only one is shown for conciseness. Others include, for instance, sudden appearance of shadows casted by large structures near the road, wet areas of the road caused by rain, glare caused by wet road and many more. Another specific example related to shadows is described separately in the following section, because many traditional video-based incident detection systems often report a large number of false alarms related to it.
2.1.2 Artefacts caused by shadows

Shadow casted by large objects travelling in the opposite direction on a nearby road pose significant challenge to video-based incident detection system. An example is shown in the image below. Here, a large truck travels towards the camera on the left segment of the highway. It casts a shadow onto the right segment of the highway, which is observed by video-based incident detection system. The travelling shadow can easily be detected as an object travelling in the wrong direction, since the direction of traffic in the observed area is opposite to that in the left segment.

This example, again, emphasizes the importance of additional intelligence in the system. X-AID™ is able to eliminate these shadows according to learned properties of vehicles and pedestrians.

Although not shown here, similar challenges can arise during the night when vehicle headlights illuminate the neighboring road. The issue is basically the same, only cause by different reason. Therefore, the solution is also the same.
2.1.3 Low quality image

In locations where there is no sufficient environmental lightening one cannot expect that incident detection will work flawlessly. Events not clearly visible in the image because of low illumination may pose a challenge for video detection. After all, it works in the same way with human visual system: some incidents simply cannot be detected in the dark. However, at minimum, a system user should expect that video-based incident detection does not produce false alarms in these cases.

If there is not enough light on the camera sensor the image will contain a large amount of noise. What is even worse, this noise greatly varies from frame to frame. Such significant noise can cause false alarms since image is constantly changing. An example of noise is depicted in the image below. This is again case when intelligent pattern-based recognition and tracking comes to aid. Using this technology only objects of interest are detected in the image. Furthermore X-AID™ analyses nosiness of the input video and reports when the video is too noisy to be used for reliable analysis.
2.1.4 Raindrops on the camera

The presence of raindrops-on-the-camera induces image distortion that has a significant negative impact on the performance of a wide range of all-weather visual sensing applications including the increasingly import contexts of visual surveillance. Affected image regions can be identified as false alarm – debris or standing vehicle. Since X-AID™ uses pattern-based vehicle / pedestrian detection no specific tunings are required for standing vehicles. However, properties of debris cannot be exactly learned by the system since debris can basically be anything that has appeared on the road at a certain point of time. Therefore to prevent false alarms raindrops regions are detected.

Detection of raindrops consists of measuring visual properties of the area separated from the background image. Also by observing sharpness compared to the neighborhood of the region, blur can be confirmed. Recognition if the blurred area belongs to background of image or a new object is present is performed.

The image below illustrates the appearance of an artefact caused by a raindrop. Figure on the left show image from the camera just before the rain has dropped on the camera lenses. In this particular case no false alarm was reported by X-AID™.

3 CENTRALIZED SYSTEM

X-AID™ is a software solution that can be installed on commonly available workstations / servers. These workstations / servers then serve as so-called X-AID™ analyzers. Video streams generated by cameras are delivered to X-AID™ analyzers over network. This makes X-AID™ hardware extremely easy to maintain since all hardware is located at a single location in the tunnel. Moreover, a faulty X-AID™ analyzer can easily be replaced, by purchasing new workstations / servers.

4 HIGH RELIABILITY

X-AID™ has proven to be a reliable solution for video-based incident detection in the pilot project for the M4 highway and has shown that can be used as a great aid to road operators in promptly reacting to potentially life threatening situations due to traffic incidents. Despite challenging conditions on the highway the system has achieved the detection rate of over 95% with false alarm rate of 0.72 false-alarm-per-camera-per-day and demonstrated an ability to excel in rigorous automatic incident detection requirements: high detection rate and low number of false alarms.
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