CASE STUDY FOR THE AMIR KABIR TUNNEL
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TABLE OF CONTENTS</strong></td>
<td>3</td>
</tr>
<tr>
<td>1 THE AMIR KABIR TUNNEL</td>
<td>4</td>
</tr>
<tr>
<td>2 X-AID™ - A CUTTING EDGE VIDEO-BASED INCIDENT DETECTION TECHNOLOGY</td>
<td>4</td>
</tr>
<tr>
<td>2.1 Varying road slopes and curved roads</td>
<td>5</td>
</tr>
<tr>
<td>2.2 Highly varying types of vehicles</td>
<td>5</td>
</tr>
<tr>
<td>2.3 Temporal and spatial variations of illumination</td>
<td>6</td>
</tr>
<tr>
<td>2.4 Simultaneous detection of multiple events</td>
<td>7</td>
</tr>
<tr>
<td>3 CENTRALIZED SYSTEM</td>
<td>8</td>
</tr>
<tr>
<td>4 HIGH RELIABILITY</td>
<td>8</td>
</tr>
</tbody>
</table>
1 THE AMIR KABIR TUNNEL

The Amir Kabir Tunnel is a two tubes road tunnel, with a part of the tunnel carries also bidirectional traffic. The two tubes differ in length. The northern tube is approximately 2 kilometers long and was opened in spring 2014, while the southern tube is planned to be approximately 1.5 kilometers long and was still under construction at the time of writing this text.

The northern tube of Amir Kabir Tunnel carries one line of traffic in its first segment, widening to two lanes in the second segment. Then it shrinks to one lane in the third segment. The fourth segment carries bidirectional traffic on two lanes, which splits into an entrance and an exit of the tunnel. Throughout the big part of the tunnel the slope of the road is changing. Moreover there are many parts of the tunnel where the road is curved. This imposes a challenge to camera calibration methodology and robust incident detection algorithms.

2 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 and a complex set of incidents that 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 its low detection reliability and high percentage of false alarms.

Examining 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 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 Amir Kabir tunnel: stopped vehicles, congestion, wrong-way vehicles, pedestrians, loss of visibility (smoke) and slow vehicles. Few of the many technical challenges while detecting these incidents in the tunnel are illustrated below.

- 95% detection rate
- 0.15 false alarms per camera per day
- Resistant to temporal and spatial variations of illumination
- Simultaneous detection of multiple events
2.1.1 Varying road slopes and curved roads

Varying-slope and curved road segments represent challenge for camera calibration and therefore estimation of moving objects’ speed. This may influence robustness of software modules observing speed as one of parameters for incident detection and classification. To tackle this problem X-AID™ is carefully calibrated prior to operation. Calibration is performed by simple placing a predefined calibration pattern (provided by Telegra) on the road in front of the camera and taking a snapshot image. Calibration pattern is placed on two-three position inside the camera field of view. From this snapshots a user can draw overlay lines on top the pattern on the image, as well as input some other known parameters. From these information the camera calibration is performed automatically.

An example of varying-slope road in the Amir Kabir tunnel is shown in figures below. The figure on the left shows two different lanes; the left lane is going uphill while the right line is going downhill; here a detection of a slow vehicle is depicted. The figure on the right illustrates a detection of a pedestrian on another varying-slope segment of the tunnel.

![Varying slope of the road](image1)

The two figures below show an example of incident detection on a curved road in the Amir Kabir tunnel. The detection quality is not affected, regardless of whether the road is straight or not. In the left figure the two pedestrians are successfully detected while the right figure show successful detection of slow vehicle and pedestrians.

![Curved road](image2)
2.1.2 Temporal and spatial variations of illumination

Non-uniformity of illumination in the scene observed by camera, either on different spatial locations or through a certain amount of time, is a typical occurrence not only in outdoor applications, but also in tunnels. There are many factors which can influence uniformity of spatial and temporal illumination. Here only few examples are shown.

In the figure below an entrance in the tunnel is shown. Since a daylight is present at the entrance the camera adapts to higher illuminated environment, causing areas further in the tunnel to appear dark. Dark areas are always a challenge for vehicle / pedestrian detection since an object of interest and its attributes are poorly visible. Therefore, in addition to variance in appearance of vehicles (pedestrians) due to their type (pose, clothes), the vehicle / pedestrian detector needs also to account variances in their illumination. In the figure below a successful pedestrian detection is illustrated even under these conditions.

Another example of temporally varying illumination is shown in the figure below. The figure shows how a scene can change over time. At first it was dark in the tunnel and then emergency lights came on. When regular lights were switched on there was a problem with the camera, which produced a yellowish figure. After some time the image has stabilized into "normal" state. In this particular period no false alarms were risen by X-AID™.
2.1.3 Simultaneous detection of multiple events

The Amir Kabir tunnel is a very dynamic environment with respect to the number of incidents happening in the tunnel. At the beginning, when the tunnel was opened, a lot of maintenance was still going on in the tunnel during the night. As a consequence, occurrence of several simultaneous incidents on the same camera is not rare. X-AID™ vehicle/pedestrian detector and tracker are able to isolate each object of interest separately and observe whether it contributes to a particular incident. An example is shown in the figure below. On the left three incidents are happening simultaneously. The black vehicle has just stopped (causing stopped vehicle alarm – yellow), the truck is reversing (causing wrong way alarm – light blue) and the pedestrian is present (darker blue box). On the right pedestrians are present (blue box) along with the slow vehicle (purple box).

![Simultaneous detection of multiple events](image)

The following image shows detection of two pedestrians (single alarm - pedestrian). However, the system is still able to conclude that two separate pedestrians are moving through the emergency lane and tracks both of them.

![Separation and independent tracking of pedestrians](image)
2.1.4 Highly varying types of vehicles

The X-AID™ vehicle / pedestrian presence detector module needs to account for high variance in appearances of different vehicle types and pedestrian poses. All types of vehicles can pass through the tunnel: from common types, such as small motorcycles, regular cars, jeeps, vans, buses, small trucks and large trucks to less common types, such as service vehicles. The detector module observes only vehicle / pedestrian attributes common for all these vehicle types and which are relevant for their separation from other objects. This allows detection of wide range of vehicle types and pedestrians without compromising the quality of the system in regard to false alarms. The two images below show an example of detection of few service vehicles present in the tunnel during the night.

![Less common types of vehicles](image)

3 CENTRALIZED SYSTEM

X-AID™ is a software solution that is 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 Amir Kabir tunnel and a great aid to tunnel operators in promptly reacting to potentially life threatening situations due to traffic incidents. Despite challenging conditions in the Amir Kabir tunnel, the detection rate of incidents is as high as 95% with enviously low rate of false alarms; less than 0.15 false alarms per camera per day are reported.
DISCLAIMER

The information contained in this document is proprietary information of Telegra. Telegra makes every effort to ensure the quality of the information it makes available. Notwithstanding the foregoing, Telegra does not make any warranty as to the information contained herein, and does not accept any liability for any injury, loss or damage of any kind incurred by use of or reliance upon the information. User understands that he/she is the only liable party. Telegra disclaims any and all responsibility for the application of the devices of software characterized in this document, and notes that the application of the device or software must comply with the safety standards of the applicable country, and where applicable, with the relevant wiring rules.

Telegra reserves the right to make modifications, additions and deletions to this document at any time and without notice. The English version of this document is the official one for all purposes. All translated versions are provided as a convenience. Any discrepancies or differences created in the translations of any other languages are not legally binding.

© Telegra 2016
DISCLAIMER: The contents and information contained in this brochure are intended for general purpose only and should not be relied upon by any person as being complete or accurate. Telegra, Telegra Inc. and Telegra India Pvt. will not accept any liability suffered or incurred by any person arising out of or in connection with any reliance on the content of or information containing in this brochure. Unauthorized disclosure or copying of any or all of it may be unlawful.