WHITE PAPER

Deploying Advanced IP Cameras in the Challenging Light Conditions of Rolling Stock Environments

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Introduction

Whenever a person or surveillance system is trying to capture clear photographs or smooth video, light plays a very important role. Most people have taken a video and seen that the resulting footage is over or under exposed because the camera is unable to adapt to the challenging light environment. Trains are noted for being a particularly difficult environment to film in and several unique challenges arise and must be overcome in order to achieve consistently smooth video footage. For example, a fast-moving train will often experience severe light fluctuations when traveling through tunnels, open air and shade, or when another train passes by. These challenges are not limited to what is happening outside of the train, but also include onboard challenges such as the lights being switched on and off, and doors opening and closing. In order to ensure clear imagery on trains, a tailor made solution is required.

Technology overview and the challenges

Auto Exposure (AE) is a technology that has been around for many years. It adjusts the shutter, IRIS, and gain (for red, green, and blue components) based on the ambient light captured by the sensor. The AE algorithm uses an image taken in ideal light conditions and stores it as a reference image. If the current image brightness is higher or lower than the reference image, the AE algorithm will adjust the current image to make it the same as the reference image. However, if the change of brightness affects a small part of the overall image, or if there is a significant light change in a small area, the traditional AE algorithm will readjust the whole image, which is a problem that must be addressed before the AE feature can be effectively deployed on trains.

The passenger consist

Two of the most difficult challenges when using the AE function on trains are caused by a combination of environmental and human factors. In a stable light environment, the AE performs its function well but in the complex light environment of a train, the standard AE algorithm cannot achieve the standards required. Due to space restrictions onboard trains, most cameras that are deployed will be compact, and are unable to accommodate an adjustable IRIS. For this reason, the AE feature that we will consider in this paper is related to the shutter and gain. A typical problem that is encountered on trains is when the AE algorithm compensates for adjustments in light when it is not necessary. An example is when lots of passengers who are wearing light-colored clothing enter the carriage and increase the

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MOXA Reliable Networks ▲ Sincere Service brightness of the image causing the AE algorithm to reduce the image brightness. If those passengers then leave the carriage, the AE algorithm will adjust the image again because the image has become darker. A similar situation occurs when the light conditions inside the carriage change due to the train entering or exiting a tunnel or passing by some buildings that block out the light. The challenge of the current AE algorithm is to keep the AE functioning as it was intended to but also avoid any unnecessary adjustments.

Solution for the passenger consist

First, light conditions are very stable in cars with a sustained light source and these cars will not experience significant light fluctuations internally as the train moves. So, the AE algorithm does not need to be that sensitive to the light fluctuations that occur outside the train. Another factor that must be considered is whether a light change within a small part of the image should be ignored. In general, the AE function will compensate when there is a change in the lighting environment. Most AE algorithms are designed to modify the image based on the overall image change. However, as the light source is generally quite stable on a train, a slight change in brightness would be attributed to a change in the objects present in the scene and would not trigger the AE adjustment for this scenario. The AE feature would still compensate if the image brightness changed considerably to ensure clear imagery. We tested our AE algorithm with a leading competitor's by installing the cameras in a car consist and filming as the train entered a tunnel. The result of our competitor's camera is shown in Fig. 1; it clearly shows that the image is too bright because the AE adjusted the shutter or the gain too much when experiencing the light change of entering a tunnel. The result of our camera is shown in Fig. 2. As you can see our algorithm adjusts the parameters only slightly and the result is smooth image quality without overexposure.

Fig. 1: Video captured from a competitor's onboard camera when entering a tunnel.

Fig. 2: Video captured from Moxa's VPort 06-2 camera when entering a tunnel.

In Fig. 3 you can compare how the ambient light change affected the brightness and see the effects of the two different AE algorithms. The line chart clearly shows that our algorithm does not alter the brightness significantly and also produces a stable image more quickly when compared to our competitor's.

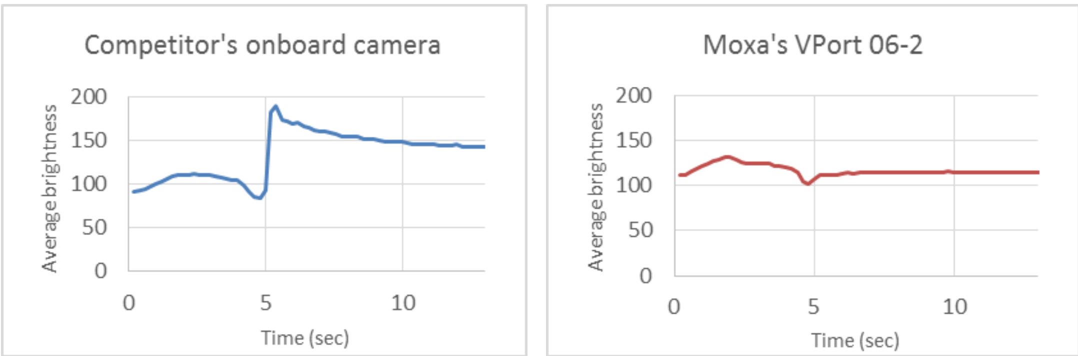

Fig. 3: A comparison of the levels of brightness when the cameras experience sudden light change.

The fluctuating light conditions not only affect image quality, but also impact some functions that help enhance security. The tampering function has traditionally been unstable when deployed in onboard environments. However, this is a problem that must be overcome for users who require excellent video quality and a reliable security system installed in their onboard environment.

Tampering detection function

The camera tampering feature automatically detects when a camera is being tampered with and issues an alert to the user. This feature performs a comparative analysis based on a digital reference image taken by the camera during a period of ideal brightness. The amount of time from detecting a possible event to issuing an alert can be split into three phases. First, there is a learning stage when a possible tampering event is detected. Second, is the detection stage, when the algorithm continues to detect if there is any significant image change based on the reference image and also uses the new image to upgrade the detection sample. Finally, once a large change has occurred, the function will trigger the event alarm. Let's take a look at how this applies to an onboard rail environment.

Onboard rail environment

In order for the tampering algorithm to accurately determine whether a camera is being tampered with, a ratio needs to be established between the expected amount of change to the scene the camera would typically experience onboard a train and when the camera is actually being tampered with. As onboard trains are constantly changing environments a clear challenge presents itself if the user wants to deploy accurate tampering algorithms onboard a train. The image brightness change can be caused by many different factors, and users do not want to receive a tampering alert for normal occurrences on a train such as the train entering a tunnel or passengers standing in front of the camera. In some scenarios, it is difficult for the algorithm to differentiate between when actual tampering of the camera is taking place and a normal image change onboard a train occurs.

Fig. 4: The car environment frequently experiences image changes.

Challenges for deployment

It is important that the tampering algorithm judges correctly if it should or should not send an alert. False alerts are when a normal event triggers the alarm, and missed alerts are when a real tampering event occurs but the camera fails to send an alert. Several challenges need to be overcome so that users can avoid these two troublesome scenarios.

1. When a camera is being tampered with, the color of the scene will change; therefore, a change of color should be counted as one of the factors for triggering the tampering alarm. Due to passenger movement or when the train moves through different environments the scene on a train will experience a change in colors. In either case, the camera's algorithm will send a false alert because it believes that a tampering event is taking place.
2. Another factor to decide whether to trigger the tampering alarm or not is when a small area of a scene undergoes significant light change. However, in a very simple or a very complex environment, it might be difficult to judge if this is an actual tampering event.

3. Different scenarios require different parameters for triggering the tampering alarm. For example, frequent and large changes to the image should be expected in a crowded car. However, there will be places on the train where the image is more stable. Thus, the feature needs to be flexible in order to cope with different situations.

After considering the three challenges above, an effective algorithm will be able to judge whether a camera is being tampered with as well as a human operator could judge. In order to increase the accuracy of the tampering function, below are some solutions to the aforementioned challenges.

How the challenges can be overcome

1. A variety of factors must be considered to determine whether the camera is being tampered with or not. The camera will not only consider the change in brightness of the image, but also the contrast and other relevant factors. Several contributing factors allow the camera to get as close to a human's judgement as possible.
2. The sensitivity level of different parts of the scene can be fine-tuned to better suit different environments, as shown in Fig. 5 below.
3. The algorithm can consider overall image changes and also partial image changes at the same time. The tampering alarm should only be triggered if the number of partial changes is sufficient to influence the overall change.

Fig. 5: The shaded red area frequently undergoes scene changes.

Conclusion

Maintaining excellent image quality onboard trains is not a simple task. Several measures and countermeasures need to be considered to meet fluctuating light conditions, and to ensure that the tampering alarm is not triggered accidentally and still functions properly when a camera tampering event occurs.

Moxa's Leading CCTV Solutions for Railways

Fig. 6: Moxa's IP camera solutions for railway applications.

Moxa's comprehensive IP CCTV solutions include IP cameras, Ethernet switches, wireless communication devices, video management software, and NVR platforms for rolling stock applications. For applications that need to operate in extreme temperatures, Moxa's portfolio of cameras includes cameras that are able to support an operating temperature range of -40 to 70°C. The built-in IR illuminator and ICR (Infrared Cutfilter Removal) are designed for low lux environments and complement Moxa's Scene Wand that includes an advanced Auto Exposure (AE) algorithm to ensure good quality imaging in challenging light conditions. These cameras are the first in the world to be compliant with the higher EN 50155 TX criteria. Moxa's cameras do not use built-in heaters or fans, thus eliminating a potential point of failure. The products are available for around 20 years, as required for use in railway applications to ensure users can easily replace models if necessary.

Visit Moxa's website at www.moxa.com/rail for product details, or subscribe to our railway newsletter at www.moxa.com/railnews to stay up-to-date with the latest railway trends and learn about Moxa's newest IP-based solutions for railway applications.