2 Dimensional, 3 Dimensional Noise Reduction in Video Surveillance Cameras

White Paper

Index

Introduction

In the context of video, signal distortion—known more colloquially as “noise”—can take the form of a random pattern of pixels that do not represent visual features in the scene being captured, or coherent noise produced by a particular device’s characteristics. A certain degree of noise is inevitable in any electronic device that transmits or receives a signal, and in video cameras, noise is a by-product of image capture.

Perhaps counterintuitively, higher-resolution cameras are more susceptible to noise. The reason is that the elements on the optical sensor are smaller and thus able to collect less light, narrowing tolerances and making errors more likely. Moreover, to compensate for the lesser amount of light collected by individual sensor elements, greater signal amplification is often applied, which itself introduces noise. More generally, for any given camera, low-light conditions will result in higher noise levels.

Quality image with sufficient light source

Noise comes along on image under insufficient light source

Types of noise reduction approaches

Put simply, individual pixels have both color and brightness—henceforth referred to jointly as the pixel’s “value” for the sake of simplicity—which in the case of noise differs from the value they would carry if they accurately represented the appearance of the area in the field of view to which they correspond. A noisy pixel may thus represent incorrect color (chroma noise) or brightness level (luminance noise).

Since the presence of significant levels of noise adversely affects image quality, reducing noise while preserving salient details is naturally a high priority for vendors. Various hardware- and software-based methods have been developed in recent years to reduce noise in the digital video captured by CMOS and CCD optical sensors. These methods can be broadly classified into two types based on their underlying technology—spatial and temporal.

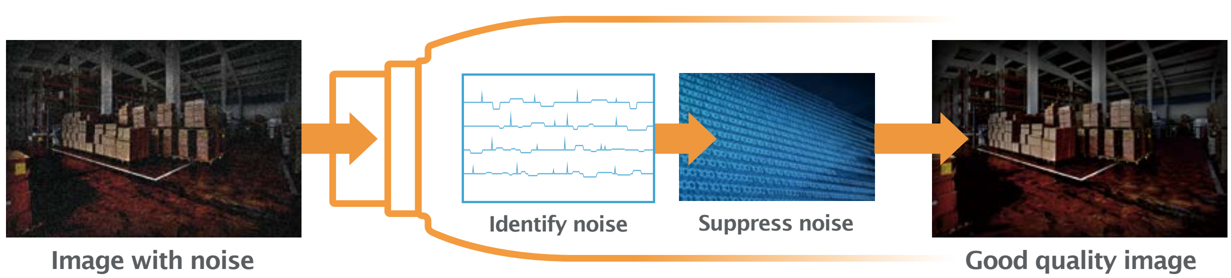
Spatial noise reduction relies on the analysis of individual frames of video. To actually reduce noise, the most common approach is to apply filters embodying algorithms designed to mitigate the effects of noise. For example, a noise reduction algorithm might assign a given pixel the median value of surrounding pixels, or an average of its own value plus those of the pixels adjacent to it. Thus, even if the pixel were noise, its “noisy” character would be diluted, taking on a value more aligned with those of surrounding pixels. A side effect of this approach is that unless special algorithms are used to identify object edges and prevent pixel averaging along the interface between the object and surrounding area, a loss of a clean border may occur.

In a temporal noise reduction scheme, averaging is applied not to the value of pixels in the same frame, but to the values of a pixel in the same position over consecutive frames. Because consecutive frames are examined, the value of a pixel at the same position over time can be easily compared, making the approach more effective than spatial noise reduction for differentiating and reducing the effects of noise in static areas that are not changing from frame to frame. A side effect of this approach, however, is the production of motion blur if an object is moving in the processed area. In this case, after noise reduction algorithms are applied, a pixel at a position in the frame where an object had appeared in previous frames but where it no longer appears will still have its value partially determined by its earlier value, leaving a faded but still visible image of the object in its earlier position.

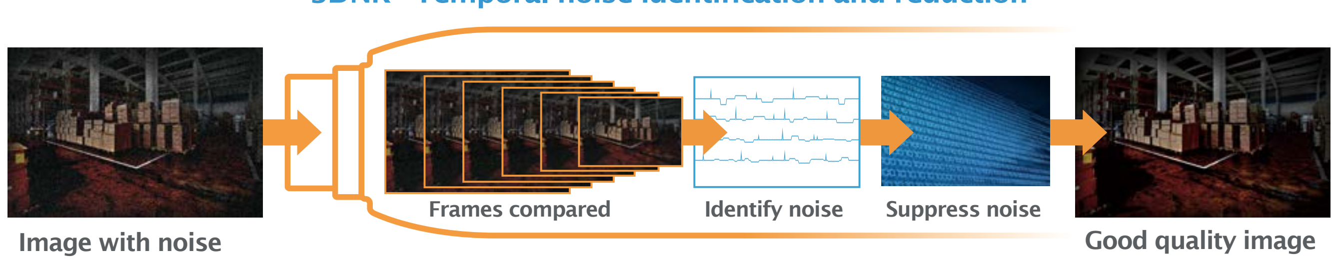
The following table summarizes the two basic noise reduction technology types.

	Spatial	Temporal
Noise detection mechanism	Analyze single frame individually to distinguish pixels that likely represent noise.	Analyze frames in sequence to differentiate pixels that likely represent noise.
Pros	Does not produce motion blur.	Very effective at reducing noise.
Cons	• Less effective at reducing noise than temporal noise reduction. • May produce some blurring of object edges.	Creates motion blur if there is movement in the processed area.

2DNR - Spatial noise identification and reduction



3DNR - Temporal noise identification and reduction

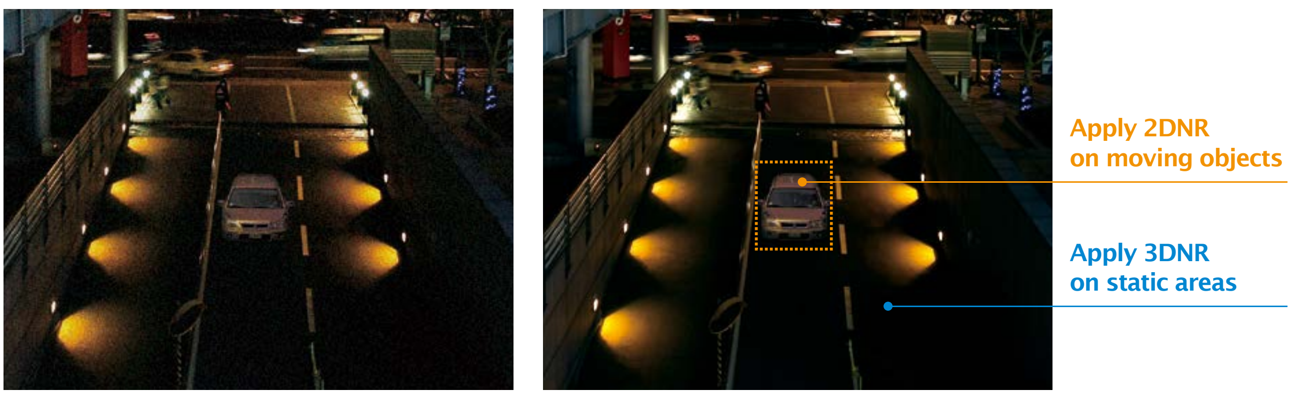


The need for an integrated approach

Due to the respective shortcomings of spatial and temporal noise reduction technologies, systems that combine both in an intelligent manner are desired, as they offer a way to compensate for these shortcomings. Some systems which offer both may not apply them simultaneously to individual video frames, but simply offer a choice of one or the other. It is important to note that simply offering an option to switch between the two types of noise reduction is less than ideal, since single frames of video may encompass static areas as well as areas where movement is taking place.

The ability to process those areas of the field of view where motion is occurring using spatial noise reduction and those with only static content using temporal noise reduction is the ideal implementation of an integrated approach. This is the type of approach that VIVOTEK has adopted in its cameras. Its 2D dynamic noise reduction (2DNR) is an optimized version of spatial temporal noise reduction technology, while its 3D dynamic noise reduction (3DNR) combines both spatial and temporal noise reduction technologies.

VIVOTEK integrates spatial and temporal noise reduction scheme to output quality video under low light



Without 3DNR | With 3DNR

Compared with 3DNR, 2DNR tends to produce superior results for moving objects, it is applied to such objects in the field of view. Meanwhile, 3DNR is applied in static areas of the field of view. In this manner, VIVOTEK cameras are able to gain the advantages of each type of noise reduction approach while avoiding their shortcomings. Additionally, VIVOTEK's implementation incorporates routines to define movement within the processed area, suppressing motion blur by distinguishing between frames where a given pixel represents an earlier state and those where the pixel represents the current state.

Benefits of noise reduction

- **Enhanced video quality for better object identification**
- **Reduced video file size for lower bandwidth and storage requirements**
- **Fewer false alarms for decreased vigilance**

Noise may be nothing more than an annoyance in video we view for pleasure, but it can obviously be a serious problem in video captured for security applications. Noise can severely compromise the effectiveness of applications such as the identification of persons of interest or vehicle license plate numbers at night, or the monitoring of dimly lit areas in an office or retail space. If noise is particularly extensive, the application may simply be infeasible.

Video noise is a frequently encountered issue with surveillance video because it is often captured under just those conditions—namely, low light levels—that easily lead to the appearance of noise. Such conditions are not only prone to producing noise, but the noise present in the video shot under low light conditions, such as night, is particularly difficult to deal with, as any attempt to increase signal amplitude to improve visibility will generally heighten the level of noise as well.

Besides enhancing video quality, VIVOTEK's 2DNR and 3DNR provide other important benefits. For one, they reduce the file sizes of captured video, by eliminating noise that adds complexity and therefore extraneous data to areas in the field of view that are actually largely uniform in appearance—for example, darkly shaded areas in video shot at night. This elimination of noise reduces bandwidth consumption when video is transmitted from the camera to an NVR or other nodes in the system. In addition, the reduced file size decreases storage needs, allowing more footage to be archived on existing equipment or saving on the costs of purchasing additional storage.

A second additional benefit of noise reduction is that it makes it far less likely that motion detection alarms will be falsely triggered by the appearance of video artifacts that do not reflect actual movement in the monitored environment. Fewer such false positives spare staff from wasted time and distractions, while lowering the possibility of decreased vigilance due to frequent false alarms.

Cameras with robust noise reduction technologies are the optimal choice for both indoor and outdoor surveillance in low-light conditions. The ability to accurately identify and eliminate noise from the video makes possible such demanding applications as identification of persons and vehicle license plate numbers even at night. As such, cameras with strong noise reduction capabilities are particularly well suited for monitoring environments like parking lots, poorly lit facilities such as warehouses, or locations not in active use at night such as offices.

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